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Acid Mine Drainage — Bunker Hill Mine Water Conceptual Model

Prepared for
U.S. Environmental Protection Agency Region 10

July 1999

Prepared by
CH2MHILL

EPA Contract No. 68-W9-0031
Work Assignment No. 31-84-105G
and
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DATE: July 28, 1999

Executive Summary

This memorandum assembles the current conceptual model for the acid mine drainage from the Bunker Hill Mine in Kellogg, Idaho. This model has been prepared to assist the Presumptive Remedy Process being undertaken by the Environmental Protection Agency (EPA) to develop a long-term acid mine drainage management remedy for the Bunker Hill Mine. The model is based on a review of the substantial research work that has been conducted at the mine and on preliminary results from a newly implemented sampling program. The model provides a review of water quality and quantity, summarizes the new sampling efforts, provides a summary of the chemistry of acid water formation, discusses known surface water, groundwater, and mine water flow paths, identifies poor quality water sources, and provides a qualitative assessment of mitigative measures.

The conceptual model was developed to facilitate revisions and to incorporate new data as it becomes available. The current sampling program is scheduled to continue through August 1999.

The major findings of the current conceptual model for the Bunker Hill Mine are summarized as follows:

- The production of acid occurs through a series of complex chemical reactions that involve the oxidation of pyrite first by oxygen and then by ferric iron. The presence of oxygen and water are required for the reaction to occur, and both air and high humidity in the mine indicate that these components do not limit the reaction.
- Water inflow to the mine occurs through a variety of surface water interception, recharge to local groundwater, and submerged workings pathways. Intra-mine flow is complex, but reasonably well understood on the 5 Level and 9 Level.
- The historical database was summarized for the site from a variety of research projects. Comparison of recent data to historical data indicates that flow and water quality in the mine is exhibiting variations that are comparable to conditions previously observed during winter months. Additional monitoring is necessary throughout the water year to evaluate seasonal changes.

- The major acid-producing areas of the mine are associated with drainage pathways from the Flood-Stanly workings. The historical data suggest that reduction of water inflow to these areas may decrease acid and metal loads, although the magnitude of the possible reduction is unknown.

1.0 Introduction

Significant long-term treatment related cost savings could be realized if the pollutant and hydraulic loads emanating from the mine were reduced. The magnitude of the savings would depend on the magnitude of the reductions and on the significance of the reductions with respect to both the type and size of acid mine drainage (AMD) treatment system being utilized. Two scenarios exist that should be considered.

The first scenario is if the acid and metal load is reduced but the hydraulic load remains unchanged. Under this scenario treatment savings would result from the reduced acid and metal load as follows:

1. Less acid and metal removal treatment chemicals would be used
2. Less treatment sludge would be generated
3. Chemical and sludge related equipment could be reduced in size

However, the cost of construction and operation of some equipment would not be reduced because this equipment would still need to be sized hydraulically for the full flow rate. Examples are neutralization reactors and filters. Neutralization reactors are generally sized on a residence time basis, which is usually most sensitive to influent flow rate, and filters are sized on a hydraulic loading rate, such as gallon of water applied per square foot of filter area.

The second scenario is if the acid and metal load is not reduced, but the hydraulic load is. Under this scenario treatment savings would result from the reduced hydraulic load primarily because of the ability to construct and operate smaller equipment sized on a hydraulic basis, such as pipelines, pumps, and filters.

The key point is that, as described, each of the two scenarios has the capability to result in a treatment savings, which would support the decision to spend money on measures to reduce the long-term acid, metal, and hydraulic loads to the treatment plant. Yet, the big question is whether there is a net savings when the cost of these measures is compared to the treatment savings. If it costs more to build and operate mitigation measures than the treatment savings gained, then, from a cost basis, the mitigation measures are not worthwhile. However, other factors besides net cost savings, such as safety concerns and environmental degradation concerns, may warrant mitigations, but like cost savings, these factors need to be evaluated on a case-by-case basis.

The discussion above is rather generic and not specific to the Bunker Hill Mine, but rightly so because the issue of cost versus realized benefit is applicable to any remediation expense. How does cost versus benefit of AMD generation mitigation measures apply to the Bunker Hill Mine? Would it be worth it to try and reduce the acid, metal, and hydraulic loads emanating from the Kellogg Tunnel? Would the cost of building and maintaining the measures be justified by the resulting savings? Because of the multiple and complex variables intertwined in these questions, there are no cut-and-dried answers and the cost versus benefit of each measure would need separate evaluation.

A key tool needed to formulate AMD mitigation measures and to allow cost versus benefit evaluations is a conceptual model of how the Bunker Hill Mine generates AMD. Ideally, the conceptual model would describe explicitly how and where the AMD is produced, and how and why seasonal fluctuations in AMD strength and quantity occur. This information could then be used to formulate focused mitigation measures, whose costs could then be compared against estimated savings. There are two categories of questions that such an ideal model would answer. These are as follows:

- How is the AMD produced?
- Where is the AMD produced?

Considerable effort has been expended over the years to answer these questions, with the hope that the answers will allow measures to be undertaken which cost effectively reduce the long-term AMD management burden.

The purpose of the conceptual model presented here is to try to provide answers to these questions. However, unlike the ideal conceptual model described above, this one is not complete. Although considerable progress has been made over the years, definitive answers do not yet, and will likely never exist. Yet, over time, if the conceptual model is continually refined it will become a better and better tool for evaluating the cost versus benefits of AMD generation mitigation measures. The conceptual model is based on the existing conditions of the current workings, and it will need to be updated as mining conditions change. At the present time, the mining is occurring at a small scale, as described in Section 2.0.

This conceptual model was prepared as part of the Bunker Hill Mine Water Management project for the USEPA under Contract No. 68-W9-0031 and Work Assignment No. 31-84-105G, and Contract No. 68-W-98-228 and WAF No. 021-RI-CO-105G.

1.1 Purpose

The purpose of this conceptual model is to further the understanding of how and where the acid mine drainage is produced to assist in the evaluation of cost-effective long-term AMD management measures. The conceptual model will provide a linkage between the four main components of the presumptive remedy (AMD generation mitigation; AMD collection, conveyance, and storage; AMD treatment; and sludge disposal) and the evaluation of costs and benefits associated with overall remedies.

1.2 Objectives

The objectives of the conceptual model are as follows:

- Provide a review of existing information on flow and quality of water within the mine.
- Summarize the recent sampling program that was implemented to verify previous investigation results and to document changes over approximately the past 15 years.
- Provide a summary of the chemistry of acid water formation and metal release

- Provide a summary of known flow paths within the mine, including surface water, groundwater, and mine water interactions.
- Identify current sources of poor quality water and identify any changes from previous sources.
- Provide a basis for the assessment of potential reductions in acid water production associated with various mitigative measures.

Table 1 provides the list of objectives and their relationship to the different components of the presumptive remedy for the mine.

TABLE 1
Summary of Objectives for the Conceptual Model
Bunker Hill Mine Water Management

Presumptive Remedy Component	Conceptual Model Objective
AMD Mitigations	Determine flow paths into the mine Identify changes in current flow paths and chemistry with respect to historic data Determine chemistry and location of acid production
AMD Collection, Conveyance, and Storage	Determine flow paths within the mine Identify maintenance requirements Determine storage capacity within mine
AMD Treatment	Identify current and expected future water quality and quantity coming from the mine Determine temporal variations in water quality and quantity
Sludge Disposal	Related to objectives included in other components

The attainment of many of the objectives listed above depends on the attainment of water quality and flow data. For this reason an AMD monitoring program was started in November 1998 to augment historical data. This program is scheduled to continue through August 1999 to capture the majority of the water year. This memorandum predates the completion of this new program, and thus should be updated as more results become available.

1.3 Document Format

This memorandum is divided into sections to present the conceptual model for the mine. These sections are the following:

- **Section 1:** Introduction
- **Section 2:** Summary of Previous Investigations
- **Section 3:** 1998/1999 Sampling Program
- **Section 4:** Chemistry of Acid Formation

- **Section 5:** Water Movement in the Mine
- **Section 6:** Water Quantity and Quality
- **Section 7:** Potential for AMD Generation Mitigation
- **Section 8:** Conclusions
- **Section 9:** Recommendations
- **Section 10:** Glossary of Frequently Used Mining Terms
- **Section 11:** References

Figures and tables are referenced throughout the memorandum. Tables are generally presented within the text, and figures are presented at the end of each section. Appendixes are included as referenced in the text.

2.0 Mine Background and Summary of Previous Investigations

2.1 Mine Background (History, Mine Setting and Geology)

The history of mining at the Bunker Hill site starts in 1885 when Noah Kellogg set out to discover gold in the Silver Valley of the South Fork of the Coeur d'Alene River. Kellogg staked a claim on land that was subsequently called Bunker Hill, built a mill, and started a small mining operation in 1886. Figure 1 in Appendix A shows the location of the Bunker Hill Mine.

At its peak, Bunker Hill was the largest silver mine in the world. The mine and associated facilities also produced corroding lead, antimonial lead, special high-grade zinc, zinc die casting alloys, cadmium, specification lead alloys, leaded zinc oxides, ore metal, super-purity antimony, sulfuric acid, and phosphoric acid. The mine was part of the Bunker Hill Mining Complex that was an integrated mining, milling, and smelting operation. In addition to the mine, the complex included a milling and concentrating operation, a lead smelter, a silver refinery, an electrolytic zinc plant, a phosphoric acid and fertilizer plant, sulfuric acid plants, and a cadmium plant. The complex occupied approximately 350 acres between the towns of Kellogg and Smelterville.

The Bunker Hill Mine encompasses 620 claims totaling 6,200 acres. From the discovery cuts, some 3,600 feet above sea level, more than 20 major ore zones were mined to nearly 1,600 feet below sea level, a vertical distance of about 1 mile. The mine contains more than 150 miles of drifts and 6 miles of major inclined shafts, and it encompasses about 5 cubic miles of disturbed ground. Figure 2 in Appendix A shows a cross section of the mine and helps convey the magnitude of the underground workings. This figure was developed by the Bunker Hill Company during the 1950s; thus, there are even more workings than depicted in as the mine has been extended down to the 31 Level.

Growing public concern about the environment in the 1970s compelled the owners of the Bunker Hill Mine to implement improvements to comply with federal air and water pollution control standards. Several pollution control systems were put in place, including acid mine drainage (AMD) control. A water treatment plant called the Central Treatment Plant (CTP) was completed in 1974 to treat the AMD.

In 1982, a 21-square-mile area of the Silver Valley, including the Bunker Hill Mining Complex, was placed on EPA's National Priorities List (NPL). The NPL site is referred to as the Bunker Hill Superfund site. A 1992 Record of Decision (ROD) specified required remedial design and remedial actions. Starting in 1994, the milling, processing, smelting, and other associated facilities with the Bunker Hill Mining Complex were demolished as part of a series of remedial actions.

BLP shut down the mine on January 17th, 1991, and had pulled pumps from all of the main pump stations by July 25, 1991. The deepest pump station prior to shutdown was located at the 23 Level. Upon pulling the last pumps, all power was turned off to the mine. About August 23, 1991, an auction was held for sale of all materials at the complex. On December 20, 1991, Robert Hopper purchased the Bunker Hill Mine from BLP, and the transaction closed on the rest of the property on April 29, 1992. Robert Hopper is the current mine owner.

From the time the power was turned off until April 20, 1992, all water from the Milo Gulch side of the mine above 9 Level (Wardner water) was diverted down the No. 2 Shaft, and all other water on the 9 Level discharged out of the Kellogg Tunnel to the Central Treatment Plant (CTP). On April 20, Mr. Hopper diverted the Wardner water to the CTP as well. By July 15, 1992, power to the mine was reestablished. On approximately December 10, 1992, the water level in the mine was three sets above the 18 Level. In January 1993, the No. 3 Hoist was again in operation; however, a cave-in within the shaft kept access to a minimum until March. By then the water level was just below the 17 Level. About October 30, 1993, the mine water line to the CTP was shut down and the mine waters were diverted into the deeper underground workings. A reading during the summer of 1993 showed the water level at about 20 feet below the 16 Level, and the water level was still below the 15 Level in October 1993. In December 1994 the pumps at the 11 Level were started and all water was again discharged to the CTP for treatment. Prior to the third week of July 1995, water below the 11 Level had risen 2 feet per day; during that week the water rose at a rate of 4 feet per day. In December 1996, the rate jumped to 6 feet per day, where it stayed until the last week of November 1998, when it once again dropped back to 4 feet per day.

The mine and mine water pumping system are currently operated by a company owned by Mr. Hopper. Approximately 9 to 11 employees work at the mine on day shift during the week, and employees are on call for night shifts, weekends, and holidays, as necessary. Job classifications at the mine include electrician, mechanic, hoistman, and laborer. The employees are non-union, and one employee is a designated foreman.

The mine is currently being worked on a small scale using an open stoping method. The areas being worked include 9, 10, and 11 level in the past 7 years; currently, the area being worked is 10 level. Approximately 500 tons of ore per month is being produced. It has been reported that Mr. Hopper does not intend to initiate larger production at this time because of financial issues; instead he is focusing on refurbishing the mine for sale or larger scale production in the future if financing issues are resolved.

The Bunker Hill Mine is located in the panhandle of northern Idaho in the Silver Valley of the South Fork of the Coeur d'Alene River. The Silver Valley is a steep mountain valley that trends from east to west approximately 2,250 feet to 4,000 feet above mean sea level.

The strata of the Bunker Hill Mine are broken by many major faults. These faults strike in a northwesterly to westerly direction and dip to the southwest between 50 degrees to 80 degrees. The underground workings of the Bunker Hill Mine lie almost entirely within the Revett and St. Regis formations of the Precambrian Belt Supergroup; these formations are made up primarily of quartzites, siltites, and argillites. The stratigraphy of the mine may be described in general terms as repeated and intermixed sections of the Revett and St. Regis formations as controlled by the extensive faults in the area.

2.2 Summary of Previous Investigations

A substantial amount of work has been conducted through various research projects related to different aspects of the Bunker Hill Mine. The majority of this work has been summarized in CH2M HILL's library database, which is accessible through the following internet address: http:\\projects.ch2m.com\secure\BunkerHill\default.html. Access is controlled through a user name and password that is available from the USEPA.

Some of the research done at the Bunker Hill Mine was directed towards understanding the flow paths, chemistry, and water quality of the mine and, therefore, is particularly useful in the development of the conceptual model. These projects are summarized in the following reports:

- *Sources and Causes of Acid Mine Drainage* (Trexler et al., 1975). Trexler measured water quality and quantity from October 1972 to February 1975 in underground and above ground locations to determine areas of recharge, acid water production, and flow paths. He used tracer tests to determine the relationship between surface water and groundwater in the Milo Creek and Deadwood Creek basins.

- *Analysis of Recharge to an Underground Lead-Zinc Mine, Coeur d'Alene Mining District, Idaho* (Hunt, 1984). Hunt investigated recharge to the groundwater flow systems in the Milo Creek area through a variety of methods including dye dilution, surface resistivity profiling, piezometer nest installation and monitoring, aerial photography, spring surveying, groundwater sampling, flow measurement, and fluorescent dye tracing.

- *Analysis of Water Movement in an Underground Lead-Zinc Mine, Coeur d'Alene Mining District, Idaho* (Erikson, 1985). Erikson studied water quantity in the upper country (9 Level and above) between February 1983 and September 1984. He conducted hydrograph analysis to understand the source and mechanism of inflow to the mine.

- *Acid Water Implications for Mine Abandonment, Coeur d'Alene Mining District, Idaho* (Riley, 1985). Riley measured water quality and quantity from March 1983 through September 1984 in underground locations in the upper country (9 Level and above). He identified areas that produced poor water quality, and presented an analysis of hypothetical reclamation alternatives, including Milo Creek diversions.

- *Analysis of Fracture-Flow Hydrogeology in an Underground Lead-Zinc Mine, Coeur d'Alene Mining District, Idaho* (Lachmar, 1989). Lachmar focused on the New East Reed Drift in the mine and investigated fault orientation and location, joint and relict bedding planes, joint infilling and flow characteristics, discharge from vertical rock bolts, pressure variation in drill holes, pressure head in piezometer nests, and constant discharge flow tests on drill holes.

- *Near-Surface Acid Mine Water Pools and their Implications for Mine Abandonment, Coeur d'Alene Mining District, Idaho* (Bretherton, 1989). Bretherton describes the temporal, physical, and chemical characteristics of the pooled water in the 3 Level Homestake workings. He provides discussion on their importance in acid water formation relative to the overall spatial and temporal distribution of water quality in the mine.

- *A Comparison of Multivariate Statistical Analysis and the Use of an Indicator Ion for the Interpretation of Water Quality Data* (Riley, 1990). Riley continued his research by monitoring flow and water quality through December 1985. He provides a discussion of temporal variations in water quality at many underground monitoring locations, and conducts detailed statistics on the sampling data.

- *Analysis of the Hydrogeologic Role of Geologic Structures with Application to Acid Mine Drainage Abatement* (Levens, 1990). Levens provides the best quantification of the tiered hydraulic conductivity systems in the rock mass. He discusses the results of the two-phase hydraulic testing that was conducted, and suggests two analytical models that may be applicable to analysis of drawdown data from observation zones located within the producing structure.

- *Analysis of the Sub-Regional Influence of Geologic Structures on Ground Water Flow In Acid Producing Metamorphic Rocks* (Demuth, 1991). The objectives of this research were to evaluate the influence of geologic structures on ground water flow on sub-regional and local scales, and to apply the results to an analysis on a regional scale. Demuth discusses the results of the three-phase hydraulic testing that was performed using inflatable packers in flowing horizontal drillholes.

3.0 1998/1999 Sampling Program

CH2M HILL initiated a sampling program in October 1998, with assistance from the Bunker Hill Mine and others, to verify the relationships of underground flow paths and poor water quality sources that had been established in previous work. The sampling program is being implemented in phases. Phase I locations were selected to identify any discrepancies between current and historical data at major flow points. Phase II locations will be selected to investigate the tributary flow paths in more detail, if necessary. The need to expand the sampling program to include Phase II locations had not yet been identified based on the first few rounds of data that had been collected when this memorandum was written. *Supplement No. 1A – Conceptual Model Interim Data Summary for the 1998/1999 Monitoring Program* in Appendix B provides a summary update on the monitoring program through April 14, 1999.

Phase I locations include 3 Level, 5 Level, and 9 Level monitoring sites. The Bunker Hill Mine is only accessible through certain areas, and access is limited to all other workings except 3, 5, and 9 Levels. Monitoring is conducted at these sites because they have been the most accessible sites in the past and at present time. Table 2 identifies each monitoring site, the rationale for monitoring, historic high flows observed at the site, and the flow measurement device selected for the site. Cutthroat flumes were used in most locations because of their ability to operate in low-gradient settings and because of the ease of construction and installation. Phase I locations and general flow directions for 3 Level, 5 Level, and 9 Level monitoring sites are presented in Figure 3-1, 3-2, and 3-3, respectively. A topographic map is included in Appendix C that shows the surface features cited throughout this document (for example, Milo Creek and its forks, Deadwood Creek, Bunker Hill Dam, Guy Caving Area, Hooper Portal, etc.).

Table 2
Mine Water Flow Measurement and Sample Collection Locations
Bunker Hill Mine Water Management

Location	Location ID	Rationale	Maximum Measured Flows (gpm)	Measured Flow Dates	Design Flows (gpm)[5]	Flow Measurement Device
Phase I Locations						
3 Level						
Homestake Drift	3HD	Measure flows from Cate Fault. Discharges through fractures to the 4 Level.	0.73[1]	7/86-10/87	1.28	2 x 18 cutthroat flume
5 Level						
Williams	5WM	Top of Williams Winze, measures tributary flows from Asher Drift, Russell Tunnel, and various ore chutes and raises downstream from the New East Reed Flume. Discharge is tributary to the Loadout	188[2], 197[3]	2/83-9/84, 1/83-4/88	345	Existing 4x36 cutthroat flume
West Reed	5WR	Flow originates from ore chutes, caved and flooded drifts west to the Cherry Raise area. Flow is normally tributary to the Becker Weir, occasionally tributary to the Reed Tunnel due to build-up downstream of the West Reed Flume.	21[2], 29[3]	2/84-9/84, 1/85-4/88	51	2 x 18 cutthroat flume
Becker	5BK	Measure flows from the west side of 5 Level. Discharges to the Loadout Area @ 9 Level.	130[2], 113[3]	2/83-9/84, 2/83-4/88	228	4 x 36 cutthroat flume
9 Level						
Bailey Ore Chute	9BO	Measures flow from the 7 Level, including the 7 Level Dam that drains the Katherine Fault at DDH #1208. Discharges to Loadout @ 9 Level.	157[2], 156[4]	12/83-9/84, 12/83-12/85	275	Existing 4x36 cutthroat flume
Cherry Raise	9CR	Measures flow coming down the Cherry Raise from below the 5 Level. Tributary to the Loadout Area @ 9 Level.	30[2], 34[4]	12/83-9/84, 12/83-12/85	60	2 x 18 cutthroat flume
Stanly Crosscut	9SX	Measures flow discharging from the Flood-Stanly workings on the 9 level. Tributary to Loadout @ 9 Level.	54[2], 28[4]	5/84-9/84, 1/85-12/85	95	Existing 4x18 cutthroat flume
Stanly Ore Chute	9SO	Drains a portion of the Flood-Stanly workings. Flow is tributary to the Loadout Area @ 9 Level.	11[2], 11[4]	2/83-9/84, 12/83-12/85	19	Bucket & stopwatch
Loadout Area @ 9 Level	9LA	Tributary to Kellogg Tunnel flume.	539[2], 621[4]	2/83-9/84, 12/83-12/85	1090	4 x 36 cutthroat flume
No. 2 (White) Raise Pumps	9PU	Will be measured at the Kellogg Tunnel by taking the difference between flow while pumps are on versus flow while pumps are off.	NA	NA	NA	NA
Barney Switch	9BS	Measures drainage from the west end of the mine including areas around the No. 3, Orr, and Skookum Shafts. Tributary to Kellogg Tunnel Flume	381[2], 254[4]	12/83-9/84, 12/83-4/84	667	4x36 cutthroat flume
Kellogg Tunnel	9KT	Measures all discharge from the Bunker Hill Mine.	2423[2], 2428[4]	1/83-6/84, 1/83-10/85	4249	Existing 12" parshall flume
Phase II Locations: Installed Only If Warranted by Phase I Data						
5 Level						
New East Reed Flume	NA	Measure discharge from exploration drill holes, rock bolt holes, and fractures in the New East Reed Drift. The drainage area is isolated from overlying and underlying mine development. Flow is tibutary to Williams Weir. The need for this flume will be based on comparison of historic and current flows at Williams Weir.	49[2], 69[4]	1/84-9/84, 1/84-12/85	121	4x18 cutthroat flume
Russel Dam Weir	NA	Flow to this weir is controlled by low dam blocking the Old East Reed Drift. Discharge originates from drill holes and fractures in the Old East Reed Drift and from an ore chute in the Governor Cross-cut. Flow is tributary to the Williams Weir. The need for this flume will be based on comparison of historic and current flows at Williams Weir.	54[2], 53[4]	12/83-9/84, 11/83-6/85	94	2 x 18 cutthroat flume
10 or 11 Level						
Deadwood Side, or Jersey	NA	The need for this flume will be based on concentration and flow data obtained from No. 2 pump. Approximately 20 - 30 gpm coming from 10 level.	NA	NA	NA	NA

Notes:
1 - Based on flows presented in Near-Surface Acid Mine Pools and their Implications for Mine Abandonment, Coeur d'Alene Mining District, Idaho. B. Bretherton, 1989.
2 - Based on flows presented in *Analysis of Water Movement in An Underground Lead-Zinc Mine, Coeur d'Alene Mining District, Idaho*. D.L. Erikson, 1985.
3 - Based on flows presented in *Near-Surface Acid Mine Pools and their Implications for Mine Abandonment, Coeur d'Alene Mining District, Idaho*. B. Bretherton, 1989, and *A Comparison of Multivariate Statistical Analysis and the Use of an Indicator Ion for the Interpretation of Water Quality Data*, J.A. Riley, 1990.
4 - Based on flows presented in *A Comparison of Multivariate Statistical Analysis and the Use of an Indicator Ion for the Interpretation of Water Quality Data*, J.A. Riley, 1990.
5 - Calculated by multiplying the highest observed flow be a factor of safety of 1.75.

Flow measurement and sampling procedures are presented in detail in the Quality Assurance Project Plan (CH2M HILL, 1998a) and the Field Sampling Plan (CH2M HILL, 1998b). A brief summary is provided in the following subsections.

3.1 Flow Measurement

Flow measurements were obtained by recording the height of the water entering the cutthroat flume at the designated measuring point. Flows are calculated from the height using free-flow or submerged flow equations developed for the flumes (Skogerboe, 1972). Several different sizes of cutthroat flumes have been installed to accommodate different anticipated flow rates. Figures 3-4 through 3-7 provide flow versus head graphs for each of the different cutthroat flumes currently operating in the Bunker Hill Mine.

Of the 12 monitoring sites included in the Phase I sampling program, two locations do not use cutthroat flumes. The Kellogg Tunnel (9KT) is measured with a 12-inch Parshall flume, and the Stanly Ore Chute (9SO) is measured with a bucket and stopwatch because of low flow rates. Figure 3-8 provides flow versus head graphs for the Parshall flume at 9KT.

Flow data available to date measured during the 1998/1999 sampling program are presented in Section 6.

3.2 Sampling and Analysis

Samples are collected from the twelve Phase I locations. However, samples were not collected from the Stanly Crosscut (9SX) during the first several sampling events. Each sampling event includes sample collection, preparation, shipment, and analysis.

Samples are collected with 1-liter wide-mouth or narrow-mouth polypropylene containers in the mine and transported to the sample preparation area. Quality control and assurance samples include one field duplicate and two laboratory quality control samples per 20 samples. Sampling is normally conducted from downstream locations first and then from upstream tributary locations to minimize the amount of sediments in the mine water. Sample preparation includes filtration and preservation according to EPA and CH2M HILL analytical methods. Samples are labeled, packaged, and shipped in accordance with EPA requirements. Samples are analyzed for the following parameters:

- Total metals: silver (Ag), aluminum (Al), arsenic (As), barium (Ba), beryllium (Be), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), thallium (Tl), vanadium (V), and zinc (Zn)
- Dissolved metals (same as above)
- Sulfate
- Total suspended solids (TSS)
- Lime demand/solids formed
- Dissolved ferrous iron

Field parameters are measured at each sample location, including temperature, pH, and conductivity. Analytical results are submitted to CH2M HILL from the laboratories within a

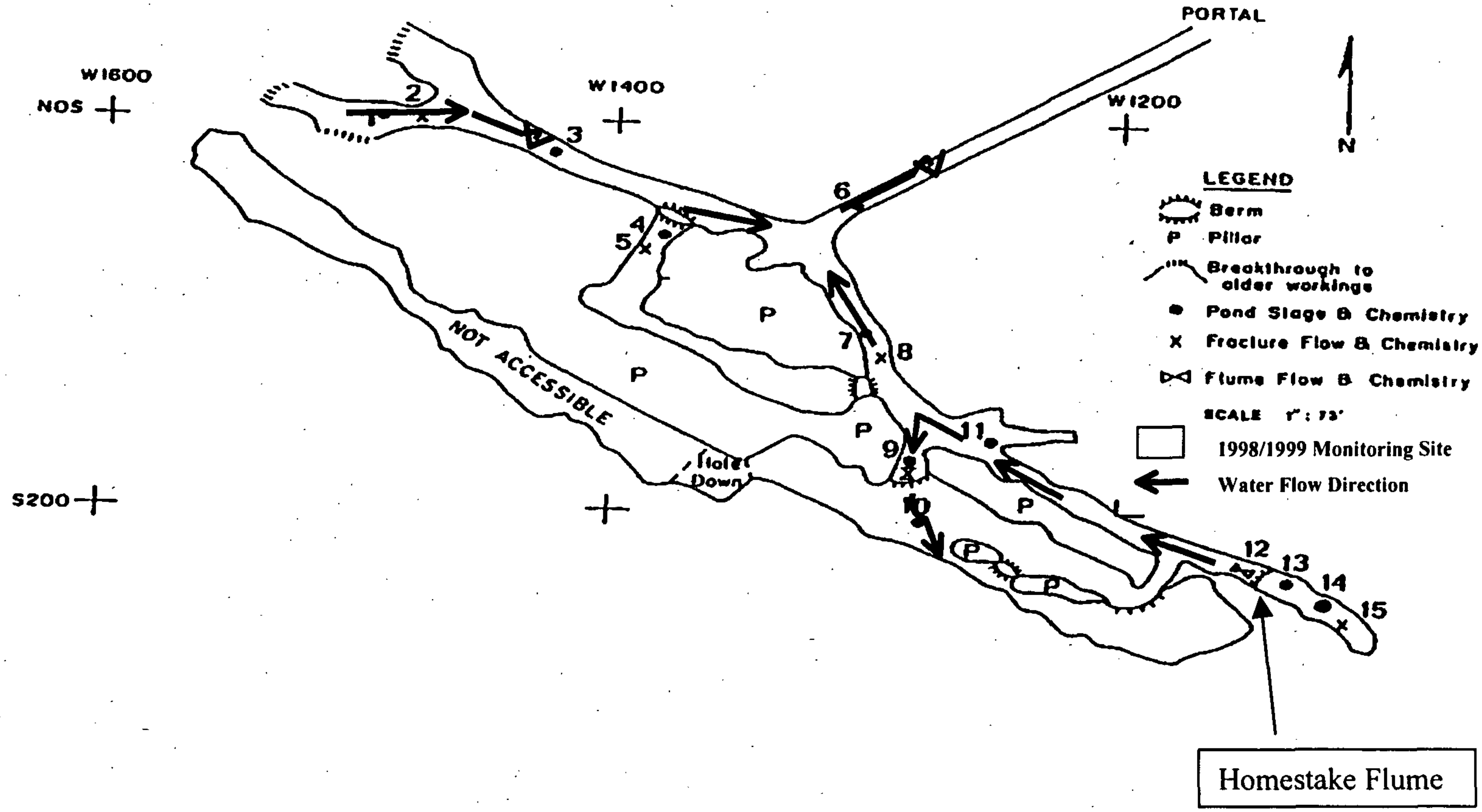

Figure 3-1
3 Level Monitoring Locations
Bunker Hill Mine Water Management
(Graphic Basis: Bretherton, 1989)

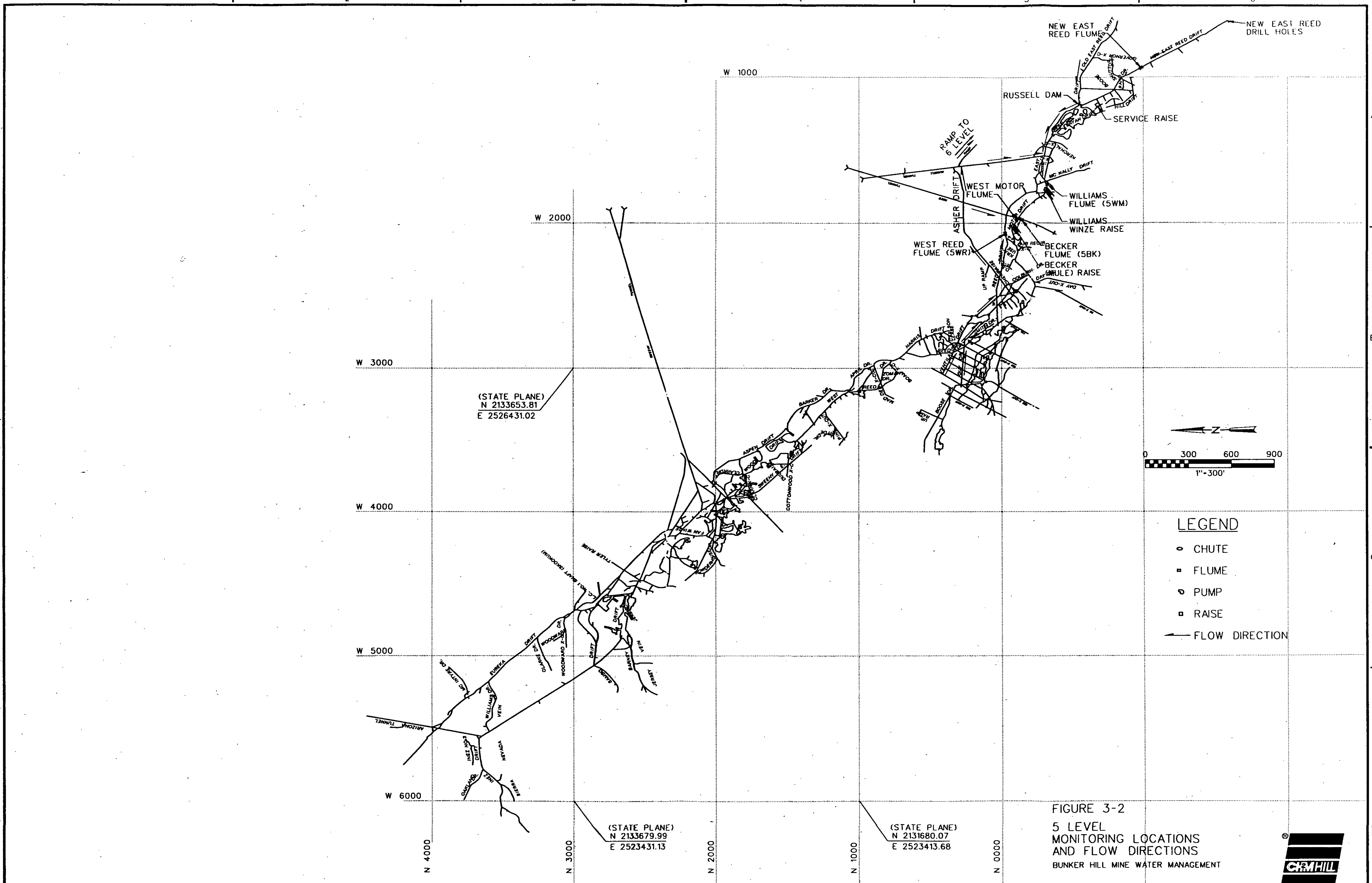

FIGURE 3-2
5 LEVEL
MONITORING LOCATIONS
AND FLOW DIRECTIONS
BUNKER HILL MINE WATER MANAGEMENT

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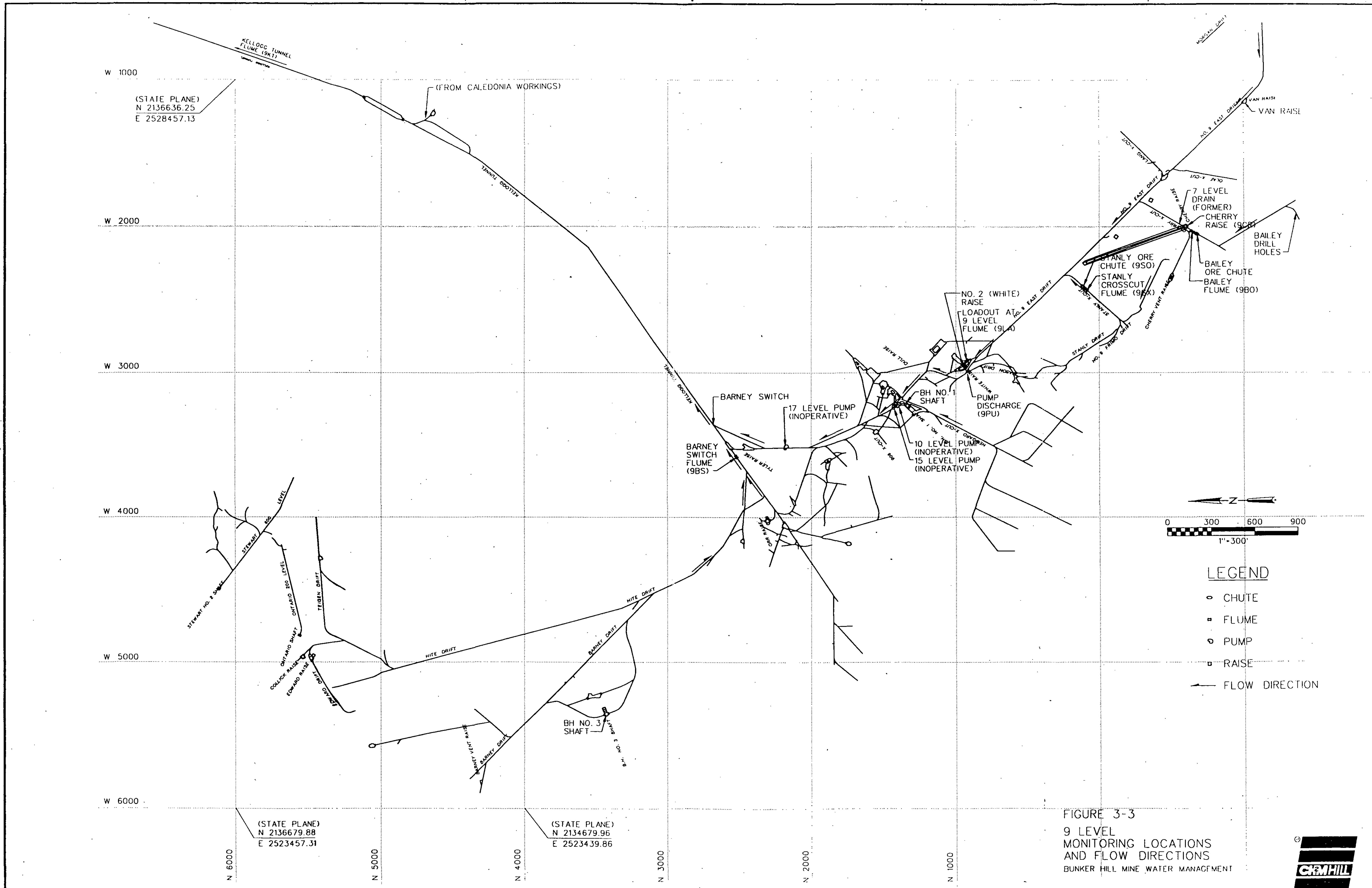
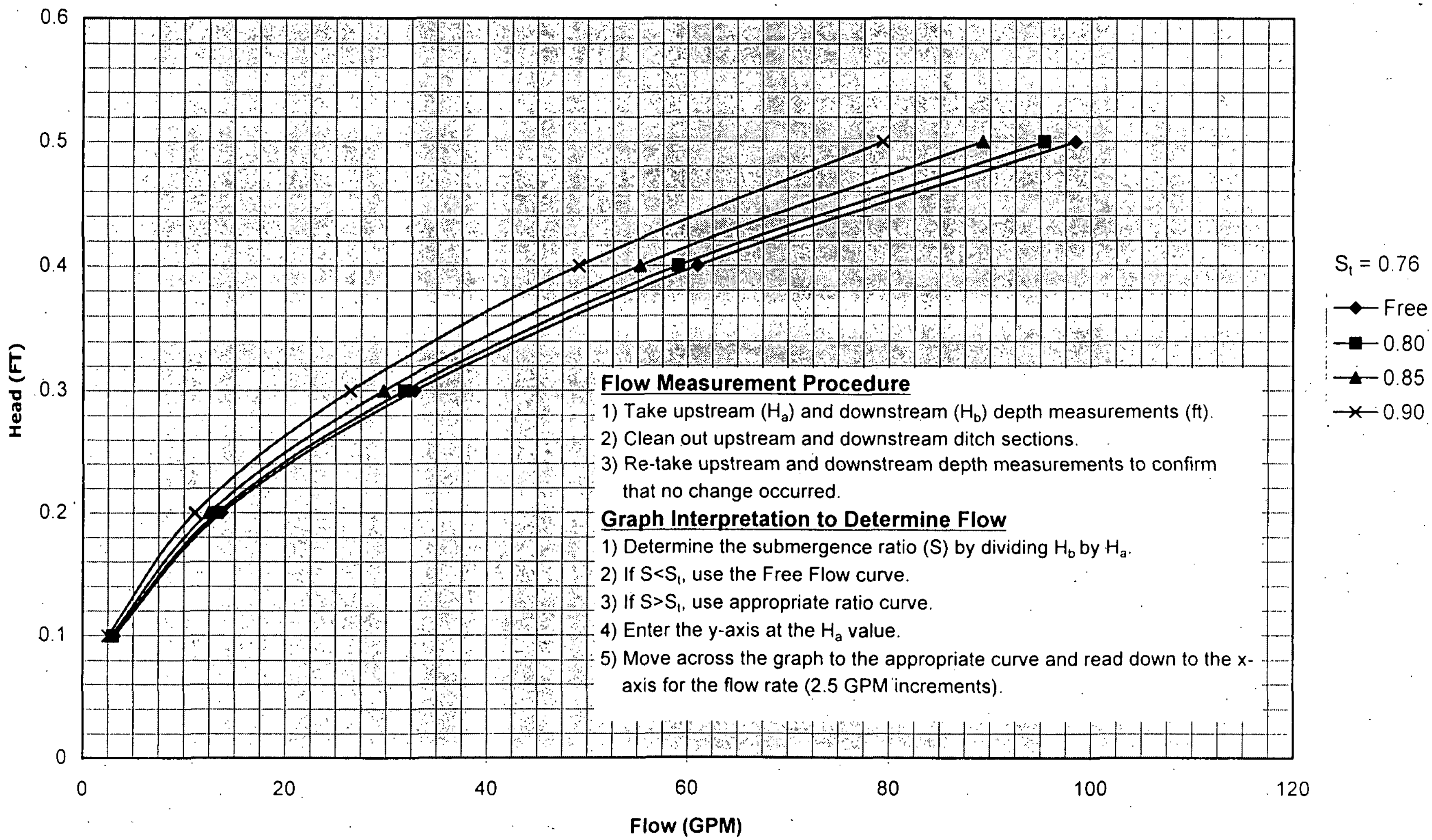


FIGURE 3-3
9 LEVEL
MONITORING LOCATIONS
AND FLOW DIRECTIONS
BUNKER HILL MINE WATER MANAGEMENT

FILE NAME: 200XX007.DLV

Figure 3-4
Flow vs. Head, 2x18 Cutthroat Flume
Bunker Hill Mine Water Management



Flow Measurement Procedure

1) Take upstream (H_a) and downstream (H_b) depth measurements (ft).
2) Clean out upstream and downstream ditch sections.
3) Re-take upstream and downstream depth measurements to confirm that no change occurred.

Graph Interpretation to Determine Flow

1) Determine the submergence ratio (S) by dividing H_b by H_a.
2) If $S<S_t$, use the Free Flow curve.
3) If $S>S_t$, use appropriate ratio curve.
4) Enter the y-axis at the H_a value.
5) Move across the graph to the appropriate curve and read down to the x-axis for the flow rate (2.5 GPM increments).

Figure 3-5
Flow vs. Head, 4x18 Cutthroat Flume
Bunker Hill Mine Water Management

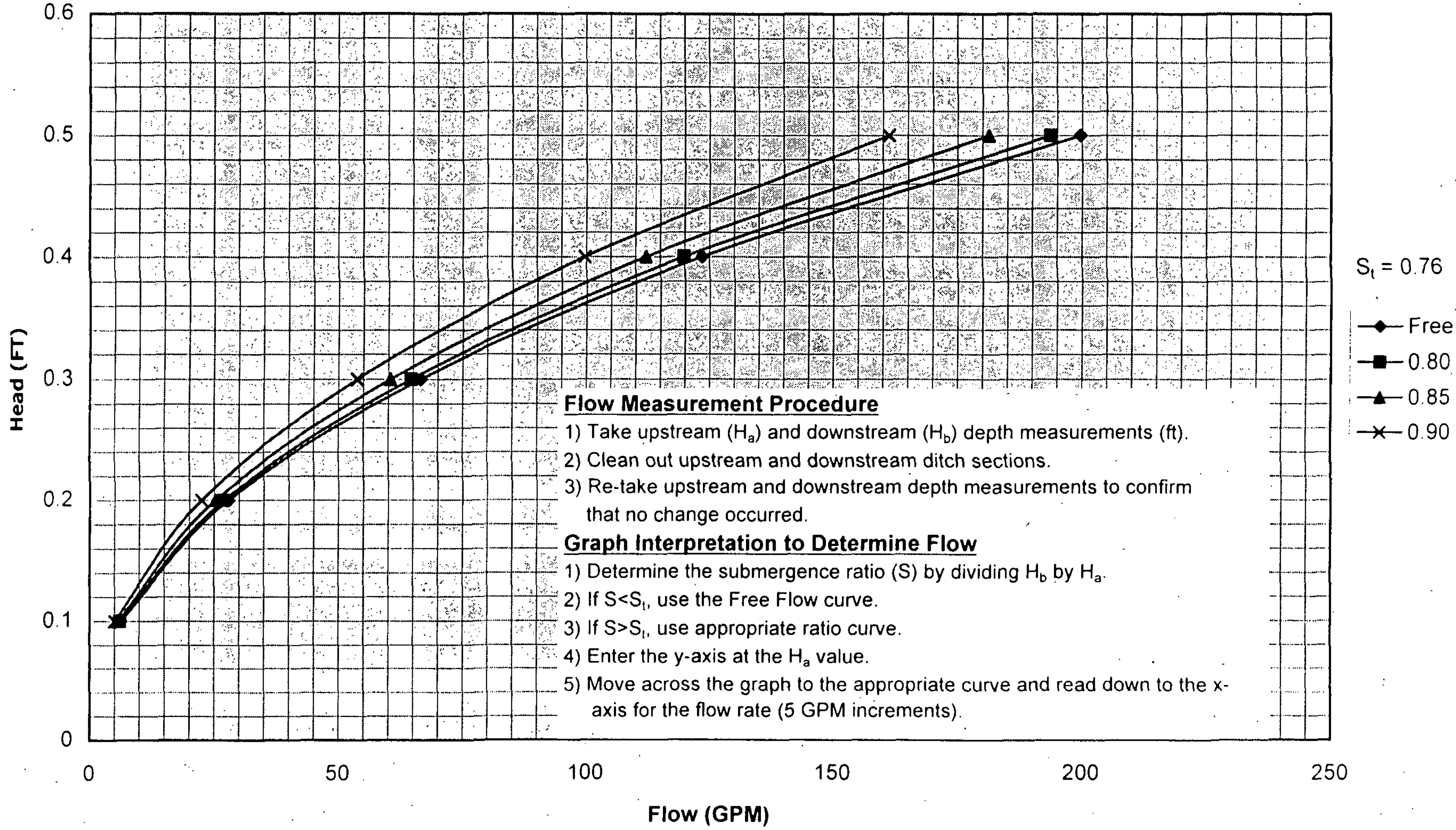


Figure 3-6
Flow vs. Head, 4x36 Cutthroat Flume
Bunker Hill Mine Water Management

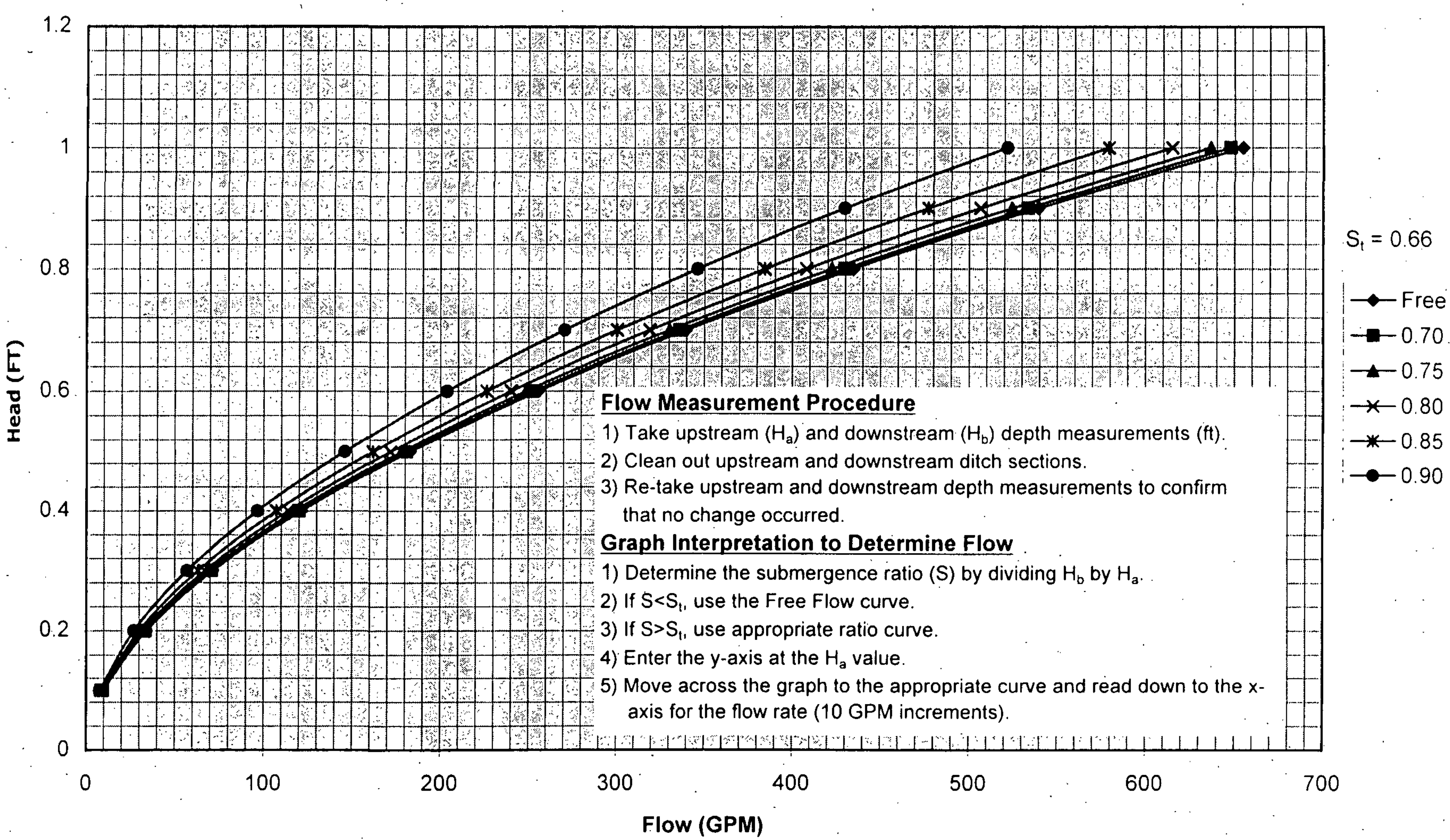


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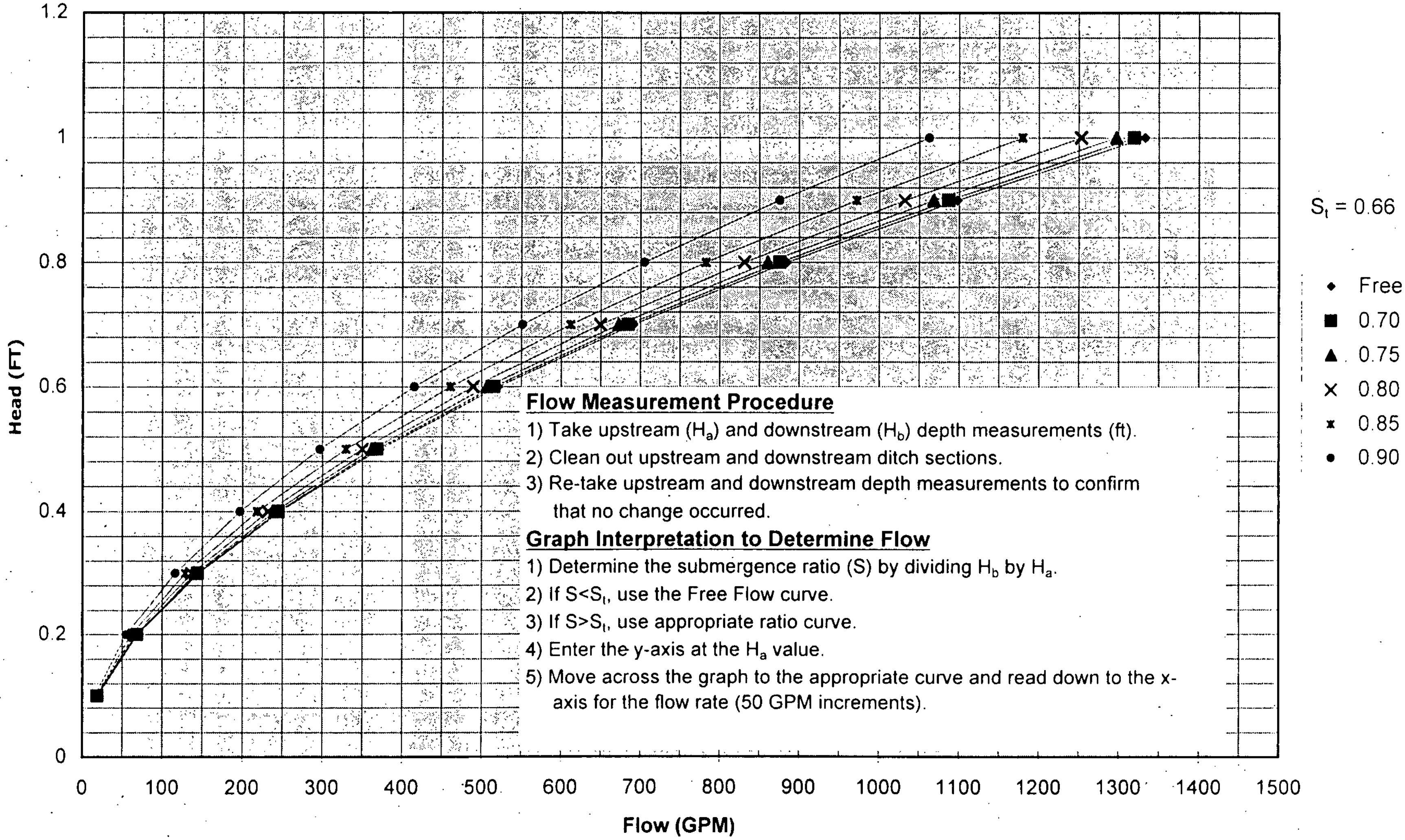
Figure 3-7
Flow vs. Head, 8x36 Cutthroat Flume
Bunker Hill Mine Water Management



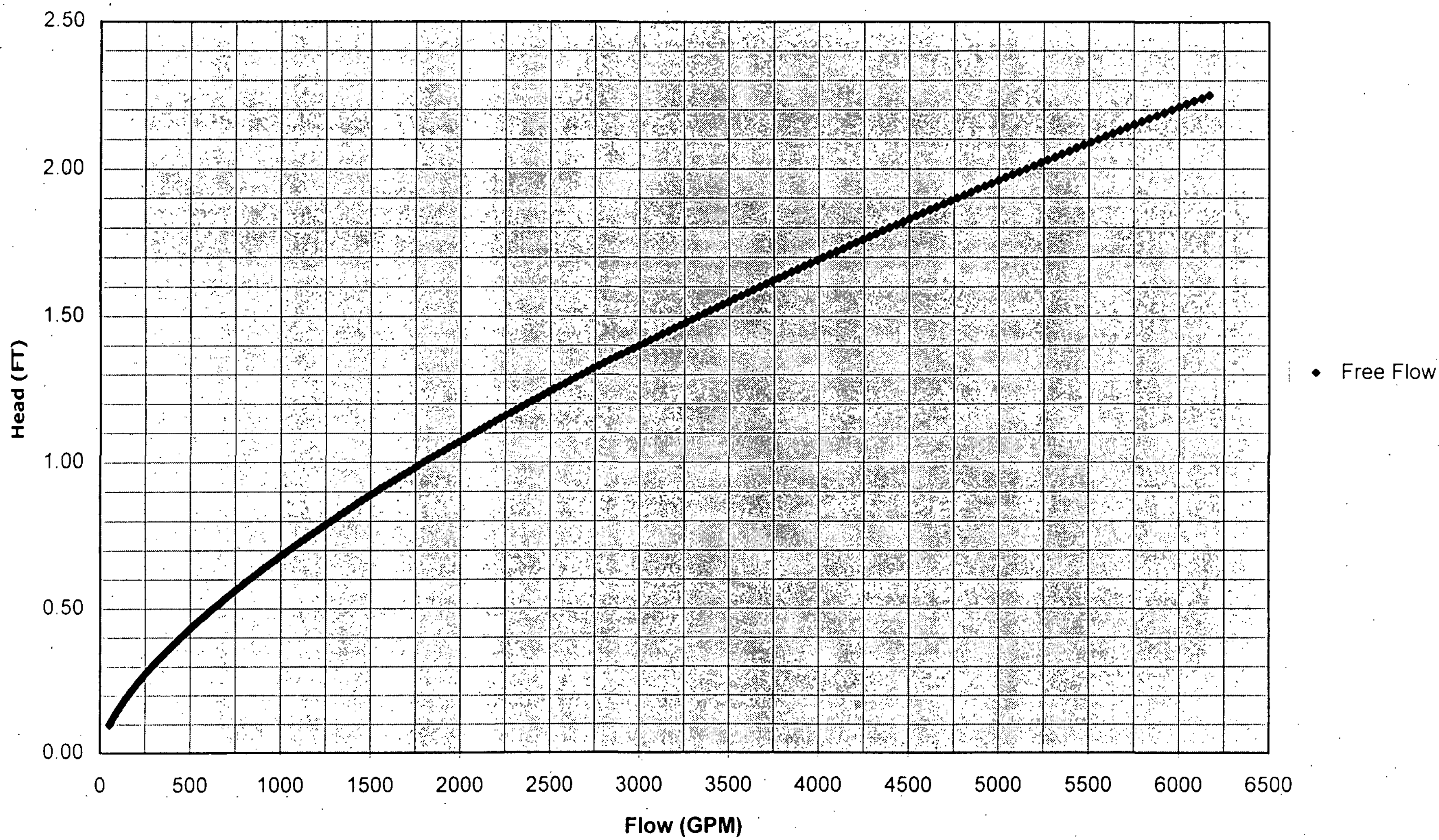
Flow Measurement Procedure

1) Take upstream (H_a) and downstream (H_b) depth measurements (ft).
2) Clean out upstream and downstream ditch sections.
3) Re-take upstream and downstream depth measurements to confirm that no change occurred.

Graph Interpretation to Determine Flow

1) Determine the submergence ratio (S) by dividing H_b by H_a.
2) If $S<S_t$, use the Free Flow curve.
3) If $S>S_t$, use appropriate ratio curve.
4) Enter the y-axis at the H_a value.
5) Move across the graph to the appropriate curve and read down to the x-axis for the flow rate (50 GPM increments).

Figure 3-8
Flow vs. Head, 12" Parshall Flume
Bunker Hill Mine Water Management



35-day turnaround time. A discussion of results from the first few rounds of sampling is presented in Section 6.

4.0 Chemistry of Acid Formation

The Bunker Hill Mine contains three general ore types based on mineralogy: Bluebird Ore, Bunker Hill Ore, and Jersey Ore (Trexler, 1975). The major mineralogical difference among the three ore types is the presence of abundant pyrite in the Bluebird Ore. Pyrite (FeS_2) is oxidized in the presence of air and water, resulting in the formation of sulfuric acid. The oxidation process occurs in three steps that are generalized in the following reactions:

Step 1: $FeS_2(s) + 7/2\, O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+$
Step 2: $Fe^{2+} + 1/4\, O_2 + H^+ = Fe^{3+} + 1/2\, H_20$
Step 3: $FeS_2(s) + 14Fe^{3+} + 8H_2O = 15Fe^{2+} + 2SO_4^{2-} + 16H^+$

In Step 1, pyrite is oxidized to sulfate and ferrous iron by oxygen present in the mine air. Step 2 is the oxidation of ferrous iron to ferric iron. This process is commonly the rate-limited reaction, but the bacteria *Thiobacillus ferrooxidans* catalyzes the reaction (Riley, 1985). In Step 3, pyrite is oxidized by ferric iron from the second equation, and hydrogen ions are released.

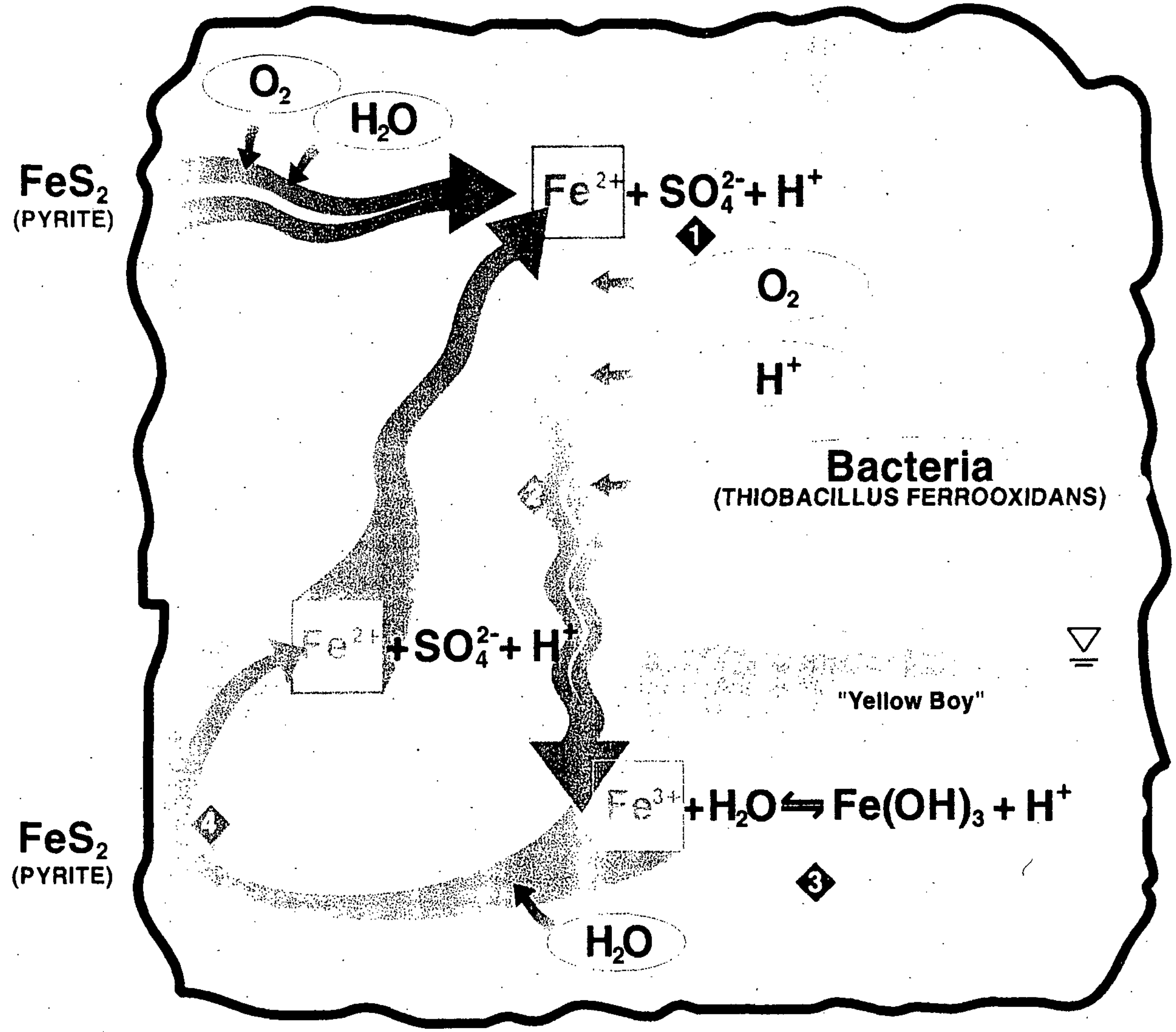
These three general steps of acid production are presented graphically in Figure 4-1. The figure shows many of these reactions occurring in the water along the bottom of the drift. However, the majority of acid production most likely occurs in moist, aerobic environments within the workings in a thin film covering the exposed pyrite deposits. The acid is periodically flushed out by seasonal water flow.

An interim step occurs between Step 2 and Step 3 that results in the production of "yellow boy" or iron hydroxide ($Fe(OH)_3$) in the drifts:

$$Fe^{3+} + 3H_2O = Fe(OH)_3 + 3H^+$$

This reaction is reversible, and low pH conditions will force the reaction to the left. Therefore, the large amount of yellow boy in the mine drainage system acts as a reservoir for ferric iron. Low pH conditions release ferric iron which can then further oxidize pyrite and create more acidic water. The ferric iron that reacts with pyrite in Step 3 is reduced to ferrous iron which can then be re-oxidized back to ferric iron in the second step. Large deposits of yellow boy will occur in areas where a poor quality water contacts a better quality water. When this occurs, the concentration of hydrogen ions is decreased, the pH rises, and dissolved ferric iron precipitates as ferric hydroxide. Historic observations at the Bunker Hill Mine suggest that this reaction occurs between a pH of 2.5 and 3.0. Above this range, ferric hydroxide is precipitated; below this range, ferric iron is dissolved in the mine water.

This brief summary of acid formation is presented in more detail in Reece (1974) and Lowson (1982).



1. $FeS_{2(S)} + \frac{7}{2} O_2 + H_2O \leftrightharpoons Fe^{2+} + 2SO_4^{2-} + 2H^+$
2. $Fe^{2+} + \frac{1}{4} O_2 + H^+ \leftrightharpoons Fe^{3+} + \frac{1}{2} H_2O$
3. $Fe^{3+} + 3H_2O \leftrightharpoons Fe(OH)_3 \downarrow + 3H^+$
4. $FeS_{2(S)} + 14Fe^{3+} + 8H_2O \leftrightharpoons 15Fe^{2+} + 2SO_4^{2-} + 16H^+$

FIGURE 4-1
CHEMISTRY OF ACID PRODUCTION
BUNKER HILL MINE WATER MANAGEMENT

2605_07 (12/16/98)

5.0 Water Movement in the Mine

Water movement in the Bunker Hill Mine occurs through a variety of inter-related hydrologic and hydrogeologic mechanisms. This complex flow system can be simplified into three main components; water sources, inflow mechanisms, and intra-mine flow. Exit flow, a fourth component, occurs through the Kellogg Tunnel, but is included in the intra-mine discussion. Each of these components is discussed in the following subsections. A generalized flow model is presented in Figure 5-1.

An interim data summary was prepared on April 28, 1999. The results of the summary showed that current flow rates correlate well with historic data. This data summary is attached in Appendix B as *Supplement No. 1A – Conceptual Model Interim Data Summary for the 1998/1999 Monitoring Program.*

5.1 Water Sources

The majority of water sources in the vicinity of the mine consist of above ground sources. Aboveground sources come mainly from rainfall and snowmelt. The precipitation eventually is collected in creeks (Milo or Deadwood) or infiltrates into the ground. Peak flow periods correspond with heavy precipitation and spring snowmelt. Infiltration recharges the local groundwater system.

5.2 Inflow Mechanisms

Water enters the mine through three primary mechanisms: surface water inflow, inflow from the groundwater system into upper workings, and inflow from submerged workings. Surface water inflows occur where workings have come close enough to intercept a portion of the surface water. Surface cavings of underground stopes (Guy Caving area), and workings in the vicinity of surface water flows (Deadwood Creek through Inez shaft, Milo Creek through Small Hopes) are examples of some of the larger known surface water inflows, although the extent of inflow is not known.

Inflow from the groundwater system to upper workings occurs according to a series of tiered hydraulic conductivities within the surrounding bedrock aquifer. A shallow groundwater system also exists at the mine. However, the shallow system is closely related to surface water, and recharges surface water or the bedrock aquifer. The primary hydraulic conductivity of the quartzite bedrock is thought to be very low. A second hydraulic conductivity exists as a result of the regional deformation and faulting of the quartzite bedrock. The regional faults strike in a north westerly to westerly direction and dip to the southwest 50 to 80 degrees. Figure 5-2 shows regional faults in the vicinity of the upper country portion of the mine. The hydraulic conductivity depends on the amount of fracturing associated with a particular fault. In the vicinity of the mine, the Cate Fault is probably a higher conductivity fault, followed by the Buckeye, Sullivan, Dull, Katherine, and Marblehead faults, in no particular order. A third tier of hydraulic conductivity is associated with northeast-southwest trending faults. These faults are less extensive than the northwest-southeast trending faults discussed above, and therefore, most likely transmit less water. A fourth tier of hydraulic conductivities exists in blocks bound by the faults. The blocks contain bedding fractures and jointing, but likely have low conductivities. The mine workings intersect these water bearing features through a variety of drifts, stopes, drill holes, and raises. The volume of water transmitted by an individual feature is a function of the conductivity of the feature and the area that is intersected by mine workings. Although the bedding planes likely have the lowest conductivity, they intersect throughout the mine workings, and, therefore, cumulatively may transmit the largest volume of water (Lachmar, 1989).

Inflow from the submerged workings is not easily quantified. The mine requires pumping to dewater to the 11 Level, indicating that the mine acts as a drain for local groundwater. It is likely that the downward component of flow induced by the mine affects both the upper country and the regional groundwater in contact with the submerged workings. This is supported by the relative elevation of the pumping level (approximately 1,970 feet above mean sea level) versus the elevation of the South Fork of the Coeur d'Alene River (approximately 2,240 feet). The present pumping rate represents the total amount of the water that drains down mine workings past the 9 Level, plus groundwater inflow to workings below the 9 Level.

5.3 Intra-Mine Flow

Once water enters the mine workings, it is conveyed to the Kellogg Tunnel through a variety of relatively complex flow paths. The following subsections provide a description of the flow paths for the 3 Level, 5 Level, and 9 Level of the mine. These levels serve as major flow paths for water, and, therefore, are important in the overall understanding of intra-mine flow. Additional levels also convey flow in the mine, but access to these levels is difficult and a detailed assessment of flow paths has not been conducted. There are also uncertainties associated with the intra-mine flow because of the difficulty in identifying all sources of AMD generation. Photographs of some typical mine drifts are presented in Figure 5-3.

5.3.1 3 Level Flow

The 3 Level consists of the Homestake Workings and the Utz Workings. These workings consist of a set of near-surface drifts and stopes within the Milo Creek drainage. The workings are in close proximity to the Flood-Stanly ore body along the Cate Fault. The Homestake Workings extend about 300 feet to the south of the Homestake Tunnel entrance. The tunnel entrance is located between the Cherry Raise and the Bunker Hill Dam at Milo Creek, at an elevation above the dam. The current monitoring location measures flow that is pooled at the end of the workings. Flow originates from the Cate Fault in this area (Bretherton, 1989). The Cate Fault is recharged in part by Milo Creek upstream of the Bunker Hill dam. Recharge to the Homestake workings also occurs from precipitation and snowmelt on the hillside above the adit. This area of the Homestake Workings discharges through fractures to the Cherry 4 Level (Bretherton, 1989), and to workings below. A map showing the major flow paths on the Homestake Workings is presented as Figure 3-1.

5.3.2 5 Level Flow

The direction and quantity of flow on the 5 Level has been studied extensively by Riley, Erikson, Trexler, and Lachmar in thesis and dissertation projects through the University of Idaho. The current understanding of intra-mine flow on the 5 Level is based on this previous work and on recent observations during site visits.

There are two major drainage locations on the 5 level: Williams Flume and the Becker Flume. Each of these is discussed in terms of its tributaries. Figure 3-2 presents the known 5 Level flow paths and the sampling locations.

5.3.2.1 Williams Flume. Water enters the New East Reed Drift through the New East Reed Drill Holes (most of which are sealed) and through bedding fractures intersected by the drift. Water flows northwest along the drift to the New East Reed Flume (a historic sampling location) and converges with flow from below the Russell Dam. The Russell Dam was built to capture flows from the Old East Reed Drift for use as drill water. The Old East Reed Drift receives flow from bedding fractures, an ore chute, and drill holes near the end of the drift. Flow continues northwest from below Russell Dam past open stopes to the west and converges with flow from the Russell Tunnel. The majority of Russell Tunnel flow comes from the Asher Drift. After converging, water flows to the Williams Flume.

From the Williams Flume, water flows down the Williams Winze to the 6 Level. It is likely that the majority of this water comes down the Van Raise to the 9 Level, but access to the 6 and 7 Levels has been difficult because of the condition of the workings, and the exact flow path cannot be easily determined.

5.3.2.2 Becker Flume. Flow at the Becker Flume originates to the west in the 5 Level workings. This flow is measured upstream of the Becker Flume at the West Reed Flume, and at the West Motor Flume (inoperative). The West Reed Flume measures flow that drains the Ventilation Drift, the Guy Drift, and the West Reed Drift and, therefore, may be hydraulically connected to the surface water infiltrations through the Guy Caving area. The West Motor Flume flow originates from a stope to the west of the flume, which receives drainage from parts of the Small Hopes Workings (4 Level). The Small Hopes and the Reed Tunnel receive recharge from Milo Creek through the bottom of the Bunker Hill Dam. Losses through the bottom of the Bunker Hill Dam have been measured at 60 gallons per minute (gpm) after the removal of a fine sediment layer (Trexler, 1975).

From the Becker Flume, water flows down through open stopes and eventually joins the Becker (Mule) Raise to the 6 Level. It is likely that the majority of this water comes out on the 9 Level via the Van Raise.

5.3.3 9 Level Flow

Water on the 9 Level flows northwest on the No. 9 East Drift to the Barney Switch area where it combines with water coming from the west side of the 9 Level and flows northeast out the Kellogg Tunnel. Pump discharge from the submerged workings is tributary to the No. 9 East Drift at the No. 2 (White) Raise. Figure 3-3 presents the known 9 Level flow paths and sampling locations. Figure 5-4 presents the 9 Level workings overlain by surface topography.

5.3.3.1 No. 9 East Drift. From the Van Raise, water flows northwest on the No. 9 East Drift to a confluence with the Cherry Crosscut. Water from the Cherry Crosscut originates from the Cherry Raise (9CR), the 7 Level Drain (no longer working), the Bailey Ore Chute, and the Bailey Drill Holes. Farthest upstream are the Bailey Drill Holes, which are currently flowing. The Bailey Ore Chute receives a majority of flow from a dam on the 7 Level built to hold drill water from Drillhole 1208, which intersects the Katherine Fault. Flow that comes down the Bailey Ore Chute and flow from the Bailey Drill Holes is measured at the Bailey

Flume (9BO). The Cherry Raise and 7 Level drain are tributary to the Cherry Crosscut flow below the Bailey flume. The origin of this water is not known. The Cherry Raise on 5 Level is dry. The 7 Level Drain was built to convey poor quality water from the 7 Level around the raise, but is no longer working. It is likely that the flow coming down the Cherry Raise originates in part from the 7 Level workings.

From the confluence of the Cherry Crosscut and the No. 9 East Drift, water flows northwest down the No. 9 East Drift until it merges with the Stanly Crosscut. The Stanly Crosscut Flume (9SX) measures flow from the Stanly Crosscut that likely originates from the Flood-Stanly Workings, and may be hydraulically connected to the surface water inflow to the Guy Caving area. The Stanly Ore Chute (9SO) merges after the Stanly Crosscut Flume, and also drains the Flood-Stanly Workings. After the confluence of the Stanly Crosscut, water continues northwest on the No. 9 East Drift where it is measured at the loadout at 9 Level Flume (9LA).

5.3.3.2 No. 2 (White) Raise Pump. The water level in the submerged workings is maintained at about 30 feet below the 11 Level with a series of pumps. A submersible pump lifts water to the 11 Level, a stationary pump mounted on the level landing lifts the water to the 10 Level, and a stationary pump on the 10 Level lifts the water to the 9 Level. The elevation of the water in the submerged workings is maintained at approximately 1,970 feet above mean sea level.

The source of water in the submerged workings is not clearly understood because of limited access to the area. Further evaluation of these workings would be helpful in assembling the conceptual model for the mine. Evaluation would require a mine dewatering effort. It is likely that water comes from fractures, faults, and bedding planes intercepted by mine workings and drill holes. In addition, water that is not intercepted by the No. 9 East Drift or the 9 Level workings northwest of the Barney Switch likely flows down to the 11 Level and contributes to the submerged workings. This includes water from Deadwood Creek that may enter through the Inez Workings and descend to the 11 Level. The 23 Level workings are connected to the 3100 Level of the Crescent Mine by the Yreka Crosscut. The Crescent Mine is located about 3 miles to the east. The hydraulic relationship between the Crescent Mine and the Bunker Hill Mine is not fully understood, but it is likely that some of the water being pumped by the No. 2 raise pumps is from the Crescent Mine. The elevation of the Kellogg Tunnel Portal is about 300 feet below the elevation of the Hooper Portal of the Crescent Mine (Hampton, 1985). This suggests that depending on the condition of the Yreka Crosscut and the elevation of water in the Crescent Mine, Crescent Mine water could drain out the Kellogg Tunnel in a non-pumping scenario.

During the time that previous investigations were being conducted in the mine, a different pump system was in place to dewater the mine down to the 27.5 Level. Three pump systems were monitored in the previous work: 10 Level discharge, 15 Level discharge, and 17 Level discharge. The current pumping system does not allow for comparisons of water flow, except to note that a greater drawdown would create larger flows.

5.3.3.3 Barney Switch. From the No. 2 Raise, water continues to flow northwest until it gets to the Barney flume. The Barney Switch drains the workings to the northwest. The Barney Switch (9BS) measures flows originating on the west side of 9 Level and is located a few hundred feet up the Barney Drift from the actual switch. These flows come from the Jersey Workings, the Hite Drift, and the No. 3 Shaft area. From the Barney Switch, water flows northeast out the Kellogg Tunnel (9KT) to the CTP. The New Caledonia Workings merge below the Barney Switch and contribute 1 percent to 2 percent of the total Kellogg Tunnel flow (Erikson, 1985).

5.4 Surface Water/Groundwater Interactions

A considerable amount of investigative work has been conducted to identify the interactions between surface water and groundwater at the mine. However, the amount of surface water infiltrating into the mine has not been quantified. This section presents a summary of the current conceptual model of these interactions. This understanding is based on a review of relevant investigations and site visits but is not complete. Additional flow paths and interactions most likely exist, and should be added to the model if they are identified. The major surface water to mine water flow paths are summarized below by surface water source.

5.4.1 West Fork Milo Creek

The West Fork of Milo Creek flows seasonally to the Flood-Stanly workings through structurally controlled conduits (faults and fractures) and direct infiltration at the Guy Caving area. When the West Fork is flowing, the flow never reaches the main stem of Milo Creek. The flow stops just above the Guy Caving Area. A portion of this infiltrating flow is measured at the West Reed Flume (5WR) on 5 Level. Water also enters the Asher Drift and flows to the Russell Tunnel and is measured at the Williams Flume (5WM). Flow also descends through the workings to the 9, 10, and 11 Levels. A portion of 9 Level flows come out at the Stanly Crosscut (9SX) and Stanly Ore Chute (9SO).

The Katherine Fault is recharged by the West Fork of Milo Creek and by precipitation (snowmelt and rainfall) in the basin above the fault. The Katherine Fault in intersected by Drill Hole 1208 on the 7 Level that provides flow to 7 Level Dam and down the Bailey Ore Chute (9BO) (Erikson, 1985).

5.4.2 South Fork Milo Creek

The Cate Fault is recharged by the South Fork, and flow discharges to the Small Hopes Workings, partly through the Bunker Hill Dam. The Buckeye Fault also receives recharge from the South Fork area, and contributes flow to the 4 Level. Although the Cate Fault system plays a major role in the overall hydrology of the mine, inflow from the Cate Fault to the upper country workings does not appear to be significant (Erikson, 1985).

5.4.3 East Fork (Mainstem) Milo Creek

The Cate Fault is also recharged by the mainstem Milo Creek above the confluence of the South Fork.

The Sullivan Fault is recharged by the mainstem and discharges to the Sullivan Workings and the Old East Reed Drift. The flow, in part, is measured at the Russell Dam (Erikson, 1985).

The Dull Fault is recharged by the mainstem and flows to the Reed and Russell tunnels. Water movement in the Reed and Russell appears to vary in proportion to the flow past the Bunker Hill Dam (Erikson, 1985).

5.4.4 Deadwood Creek

Surface water flow enters the Arizona-Oakland-Inez workings and descends to 11 Level (Trexler, 1975).

The West Fork Milo Creek has been suggested as the biggest surface water contributor to mine water (Hunt, 1984). However, inflow from bedding planes intersected by the mine workings may contribute more water to the mine than surface water (Lachmar, 1989).

Surface areas where the slope of the hillsides is aligned with the dip of the bedding planes likely receive less recharge than across where the dip is perpendicular to the hillside. This may be why the Sullivan workings are relatively dry.

6.0 Water Quantity and Quality in the Mine

This section presents a summary of the current understanding of water quantity and quality in the Bunker Hill Mine. The discussion is largely based on previous investigative work. The complete set of analytical results from the 1998/1999 sampling program had not been received for the first few sampling events at the time this memo was drafted. A more recent data summary is presented in Appendix B. It is recommended that this model of water quality be revisited and updated throughout the sampling program as appropriate.

A review of previous investigations was conducted to assemble a database of historic data for each current monitoring location. This database is summarized in Table 3, and presented as Appendix D. Section 5 provides a description of the locations listed in Table 3. The values presented in the table represent averages over the indicated duration of the investigation. Water quantity for the mine is discussed in terms of flow rates in gallons per minute. Water quality is discussed in terms of zinc concentration, pH, and conductivity. In addition, the zinc load is calculated from the flow and zinc concentration to provide supplemental information on water quality. The zinc ion (Zn^{2+}) is used as an indicator of overall water quality in describing the metal loading in the mine. Zinc is prevalent at the Bunker Hill Mine; it is highly soluble in water, does not form hydrolysis precipitates readily, and is a good representative of conductivity (Riley, 1990).

The summary in Table 3 contains values that have been averaged throughout the study period conducted by Riley and Bretherton between 1983 and 1988. Although each location demonstrates a degree of seasonality, the average values are appropriate for general comparison this early in the 1998/1999 sampling program.

6.1 3 Level Water Quantity and Water Quality

Analytical results for the 3 Level from the current sampling program had not yet been received from the CLP laboratory at the time this memo was drafted. In the absence of zinc data, a preliminary comparison of water quality can be conducted using the field parameters. Location 3HD was monitored on November 20, 1998, and December 17, 1998. The results for pH from the pool above the flume were 2.68 and 2.65, respectively. Conductivity results were 630 and 650 μmho/cm, respectively. The average values for pH and conductivity at 3HD are 2.5 and 830 μmho/cm. Figure 6-1 presents a plot of flow and conductivity data versus time for 3HD. The recent conductivity values appear to be within the range of historical results for this location.

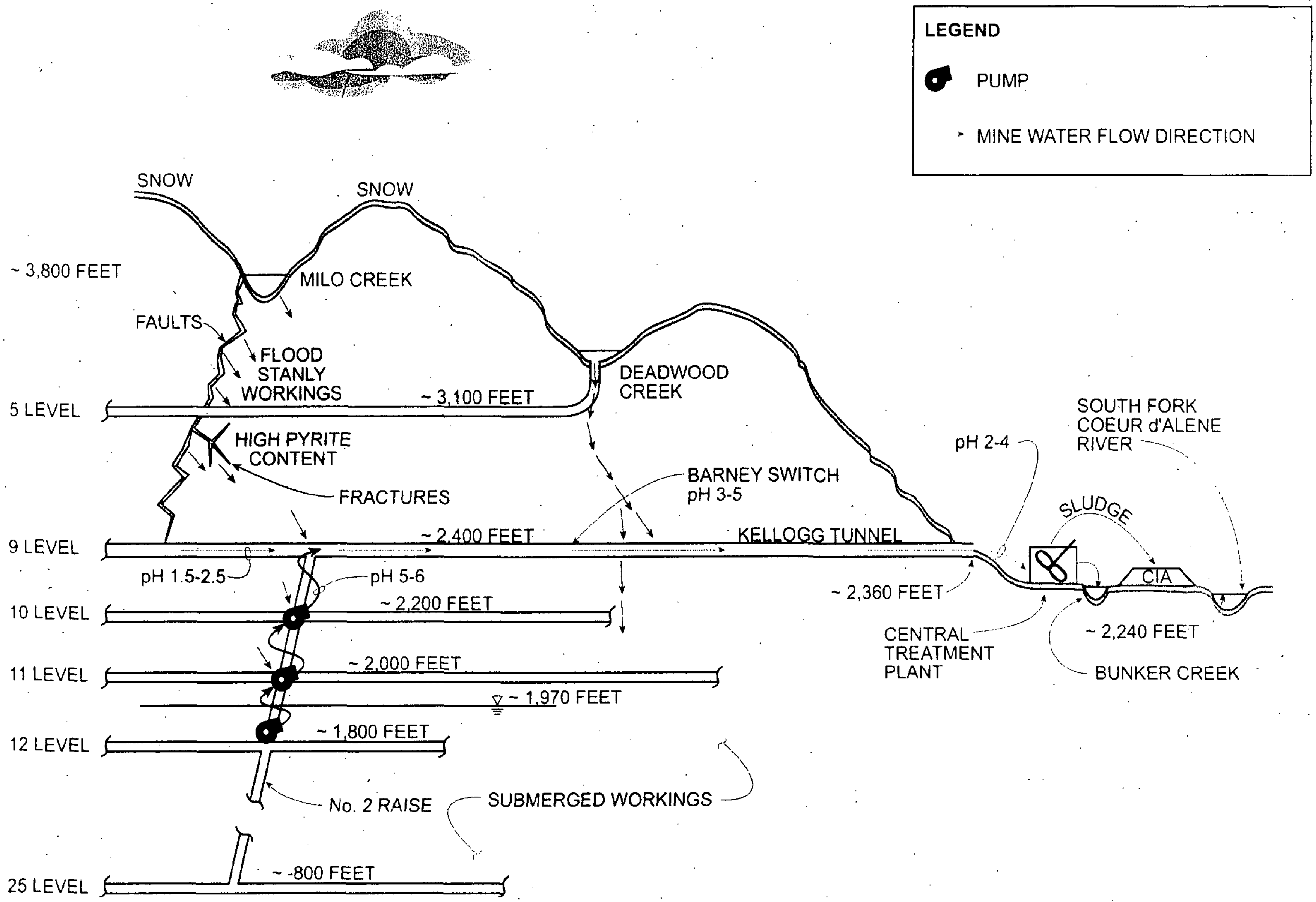


FIGURE 5-1
GENERAL FLOW MODEL
BUNKER HILL MINE WATER MANAGEMENT

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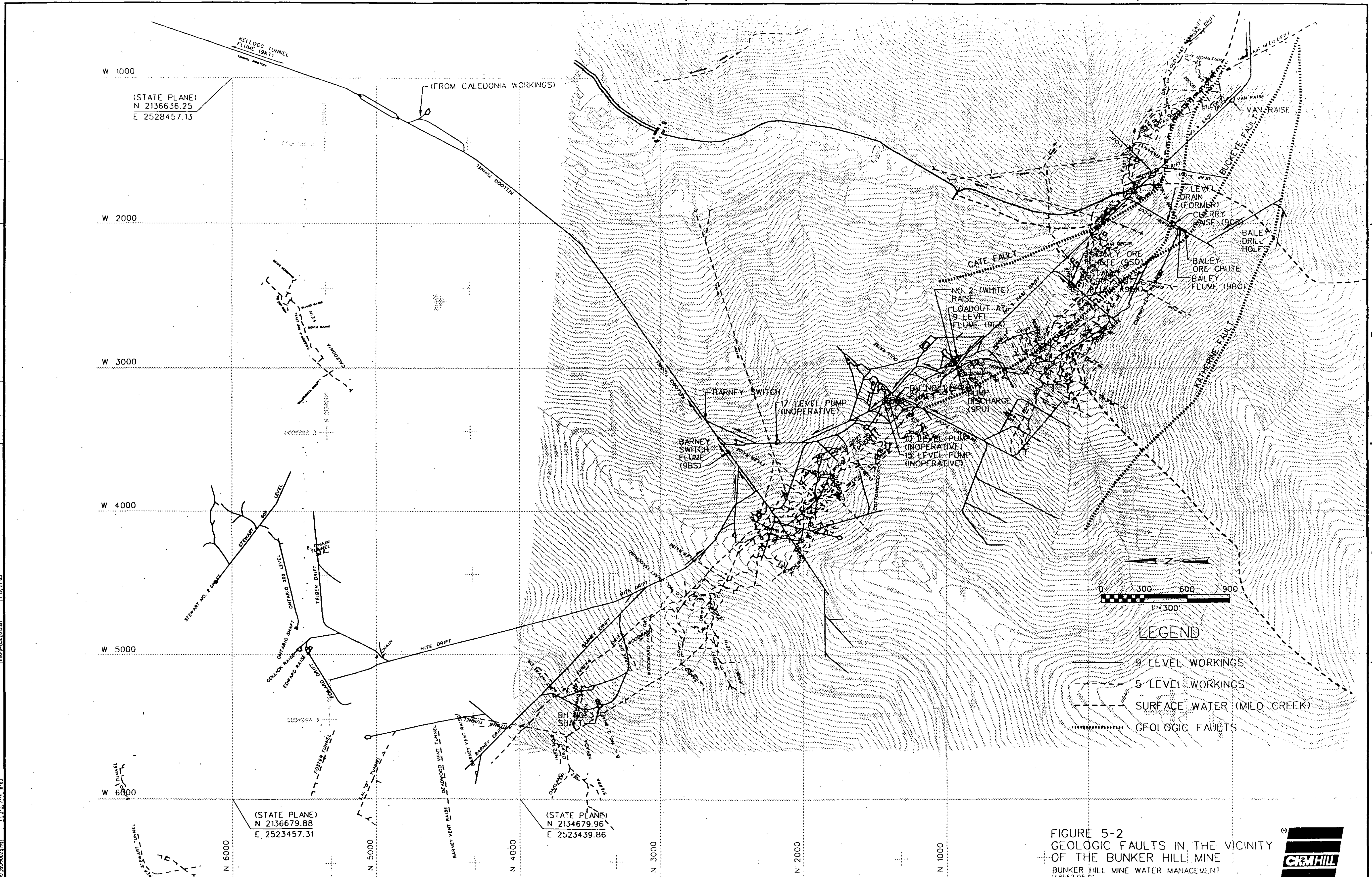

FIGURE 5-2
GEOLOGIC FAULTS IN THE VICINITY OF THE BUNKER HILL MINE

BUNKER HILL MINE WATER MANAGEMENT
148562.05.01

CH2M HILL

FILE NAME: 90VXX001.DLV 22 JAN 1999

5 Level: Looking upstream of the Williams Flume.

5 Level: New East Reed Drift

FIGURE 5-3
TYPICAL DRIFTS IN THE BUNKER HILL MINE
Bunker Hill Mine Water Management
148562.05.01

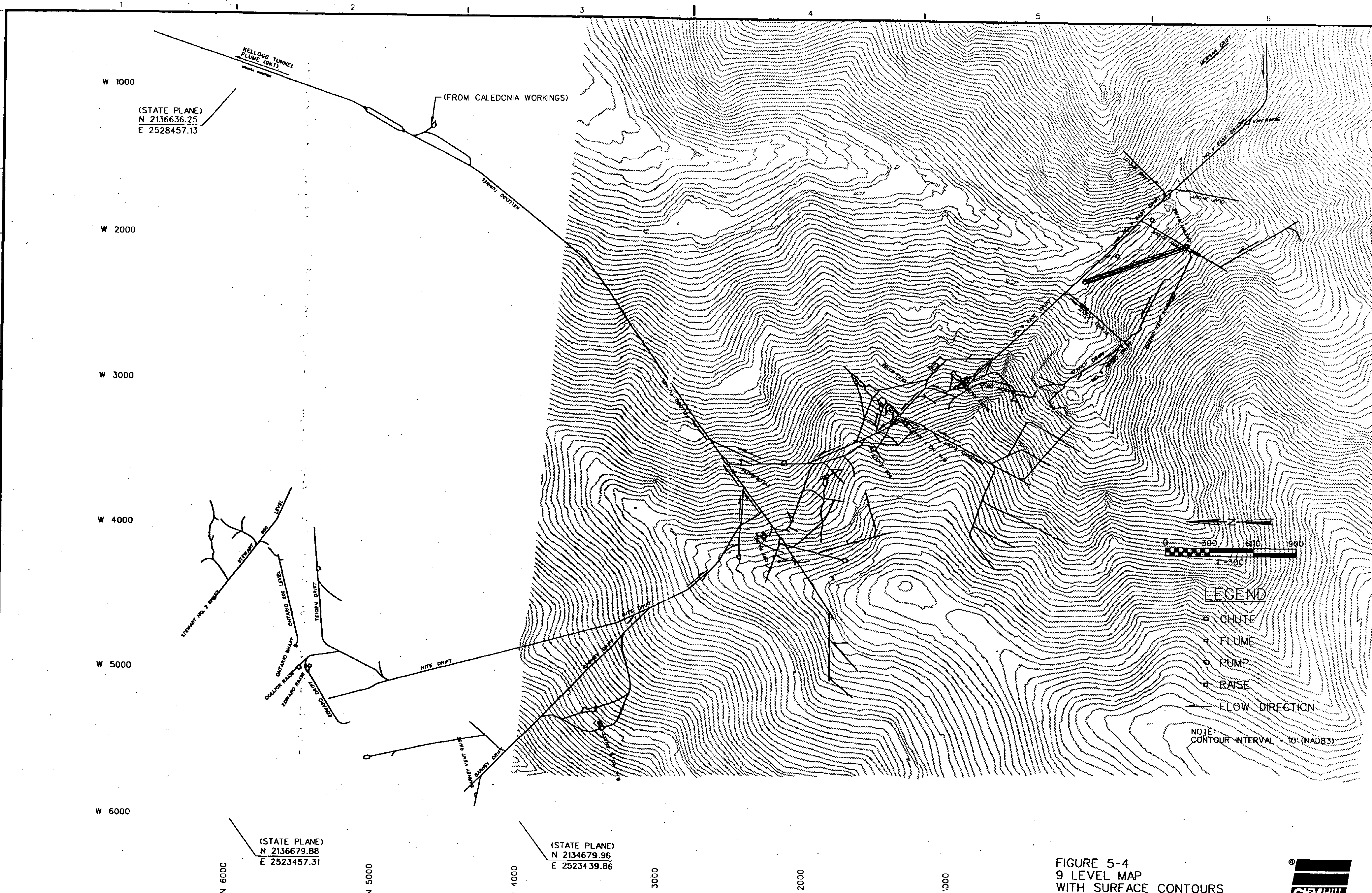

FIGURE 5-4
9 LEVEL MAP
WITH SURFACE CONTOURS
BUNKER HILL MINE WATER MANAGEMENT
148562.02.01

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PRELIMINARY

TABLE 3
Summary of Average Water Quantity and Water Quality Data for Monitoring Locations
Bunker Hill Mine Water Management

Location I.D.	Location Name	Zinc (mg/L)	pH	Conductivity (μmho/cm)	Flow (gpm)	Zn Load (lb/day)	Dates
3HD	Homestake Drift	38.1	2.5	830	0.25	22.4	3/12/86 to 4/14/88
5WM	Williams Flume	29.7	3.4	340	143	50.9	1/27/83 to 4/14/88
5WR	West Reed Flume	888	2.5	4262	9.1	96.6	10/6/83 to 4/14/88
5BK	Becker Flume	246	2.7	1,815	43.6	129	1/27/83 to 4/14/88
9BO	Bailey Ore Chute	0.3	3.7	105	118	0.4	2/25/83 to 12/18/85
9CR	Cherry Raise	1,830	2.7	6,746	15.3	337	2/25/83 to 12/18/85
9SX	Stanly Crosscut	1,630	2.4	6,576	11.8	231	6/8/84 to 12/18/85
9SO	Stanly Ore Chute	17,110	2.0	25,660	2.0	409	2/17/83 to 12/18/85
9LA	Loadout Area at 9 Level	344	2.7	2,474	436	1,800	2/10/83 to 12/18/85
9PU	No. 2 Raise Pump	NA	NA	NA	NA	NA	NA
9BS	Barney Switch	3.8	5.2	462	197[a]	8.9	3/24/83 to 12/18/85
9KT[b]	Kellogg Tunnel	111	2.7	1,993	1,660	2,210	1/25/83 to 10/31/85

[a] Flow measurements from the Barney Switch were only collected a total of seven times.
[b] Data for the Kellogg Tunnel includes pump discharge that dewatered the mine to 27.5 Level. Current flow and loading is expected to be less than during the period this data was obtained.
NA = Not Available.

mg/L = milligrams per liter
lb/day = pounds per day
umho/cm = micromhos per centimeter
gpm = gallons per minute

The flow at 3HD on November 20, 1998, was 0.1 gpm, and on December 17, 1998, it was 0.02 gpm. The flow data recorded in the Homestake were compared to historic data collected between March 1986 and April 1988 and appear to be within the seasonal range of historic data.

6.2 5 Level Water Quantity and Water Quality

Table 4 presents the current data collected for 5 Level as part of the 1998/1999 sampling program.

TABLE 4
Summary of Data for 5 Level
Bunker Hill Mine Water Management

Location	Zinc (mg/L)	pH	Conductivity (µmho/cm)	Flow (gpm)	Zn Load (lb/day)	Date
5WM	NA	4.68	155	NA	NA	11/6/98
	NA	2.73	400	116	NA	12/17/98
5WR	NA	2.81	900	1.0	NA	11/6/98
	NA	2.23	3,300	0.7	NA	12/17/98
5BK	NA	3.17	550	13.2	NA	11/6/98
	NA	2.31	2,100	20.0	NA	12/17/98

NA = Not Available.

Figure 6-2 presents historical flow and conductivity data for the Williams Flume for the period between January 1983 and March 1988. Conductivity and pH data (Table 4) appear to vary around the historical average values (Table 3). The current flow is slightly less than the average of 143 gpm, but very similar to historic winter flows (Figure 6-2). Historically, the Russell Dam and the New East Reed Flume each contributed about 50 gpm average to the Williams Flume.

The data for the West Reed Flume indicate that pH varies around the average and conductivity and flow are below average. Figure 6-3 presents the historical data for 5WR. The recent flow values are among the lowest recorded at this location during the previous study period. This may be due to seasonal variations in the quantity of water at this monitoring location. The West Reed Flume had been in a different location until January 1999 than the current location. This could account for the difference in flow rates as well.

Figure 6-4 presents the historical data set for the Becker Flume. The tables show that recent data exhibit pH and conductivity values that bracket the average values (Table 3). The recent flow is less than the average flow of 43.6 gpm, and is within the historic winter values (Figure 6-4).

Additional data are needed to determine if these values represent a seasonal occurrence or a change in the overall water quality and quantity of the upper workings.

6.3 9 Level Water Quantity and Water Quality

A summary of recent data collected on the 9 Level is presented in Table 5. Mass balances for zinc loading will be conducted as data are available. Comparison to Table 3 suggests that the recent data for 9BO exhibit pH and conductivity values that are similar to the average values. The flow at 9BO has been slightly higher than average. Figure 6-5 presents the historic flow and conductivity data for 9BO. The data suggest that the flow decreases in the winter months.

TABLE 5
Summary of Data for 9 Level
Bunker Hill Mine Water Management

Location	Zinc (mg/L)	pH	Conductivity (µmho/cm)	Flow (gpm)	Zn Load (lb/day)	Date
9BO	NA	3.55	340	149	NA	11/13/98
	NA	4.42	92	120	NA	12/1/98
	NA	4.45	220	148	NA	12/16/98
9CR	NA	2.11	4,080	1.0	NA	11/13/98
	NA	2.1	3,380	1.0	NA	12/1/98
	NA	2.02	5,000	1.7	NA	12/16/98
9SX	NA	2.12	4,380	0.9	NA	11/13/98
	NA	NA	NA	2.1	NA	12/1/98
	NA	2.06	4,100	4.2	NA	12/16/98
9SO	NA	1.65	20,400	1.0	NA	11/13/98
	NA	2.33	18,000	1.0	NA	12/1/98
	NA	1.60	>50,000	1.2	NA	12/16/98
9LA	NA	2.5	1,480	322	NA	11/13/98
	NA	2.96	1,280	372	NA	12/1/98
	NA	2.81	1,130	346	NA	12/16/98
9PU	NA	5.21	3,350	NA	NA	11/13/98
	NA	5.04	3,300	NA	NA	12/16/98
9BS	NA	6.01	1,400	95	NA	11/13/98
	NA	6.06	520	133	NA	12/1/98
	NA	5.94	1,530	151	NA	12/16/98
9KT	NA	2.93	1,100	495	NA	11/13/98
	NA	2.57	1,150	532	NA	12/1/98
	NA					12/17/98

[a]Pumps were inoperative on 12/1/98.
NA = Not Available.

The recent data for the 9 Level Cherry Raise (9CR) monitoring station exhibit lower pH, conductivity, and flow when compared to the average values. Figure 6-6 suggests that flow and conductivity vary widely, and lower values are typically observed in the winter months. The recent data can most likely be attributed to the seasonal variations observed at 9CR. The flow rates at 9CR have increased after diversion of more water down the raise in early January 1999. The more recent 9CR flow is in closer agreement with the historical data.

Data for 9SX, Stanly Crosscut, indicate that water at this location recently has a slightly lower pH, a lower conductivity, and a lower flow than the historic average. Figure 6-7 shows that the difference is most likely due to seasonal variations.

9SO, Stanly Ore Chute, data show that recent flow values are slightly lower than the average values. Values for pH are close to the average values observed at this location. Conductivity has varied between 18,000 and greater than 50,000 µmho/cm. Again, Figure 6-8 shows that seasonal variations that naturally occur in the Flood-Stanly inflow to the mine are the reason for the difference. The high spike inflow associated with the late spring provides additional evidence of the interaction between flow in West Fork Milo

Creek and flow coming from the Flood-Stanly workings. This source continues to exhibit the poorest water quality of the monitoring stations.

All of the monitoring locations discussed above are tributary to the 9 Level Loadout Area (9LA). The seasonal variation observed in these upgradient locations is also evident at 9LA. Both flow and conductivity are significantly lower than the average, but within the historical range for November/December. The pH values are near the average values observed during the previous investigations. Figure 6-9 presents the historical flow and conductivity data for 9LA.

Data that are being collected from 9 Level No. 2 (White) Raise Pump (9PU) are not directly comparable to historic data because of the fact that different pumping systems were being used. Weighted averages for flow, zinc, pH, and conductivity were developed for the old pump system based on data obtained between March 1983 and October 1985. These averages are 863 gpm, 45.5 mg/L, 3.9, and 1,690 μmho/cm, respectively. Table 5 shows that current submerged workings data exhibit higher pH and conductivity. Flow from 9PU has not been directly measured, but recent data from the Kellogg Tunnel (8/31/98 to 11/12/98) show that the average difference in flow between pumping and non-pumping conditions is about 790 gpm. This value has not been corrected to account for the interval that the pumps are not operating, and such corrections would reduce the value.

Water from 9LA merges with the flow from the Barney Switch (9BS) before exiting the mine at the Kellogg Tunnel. The recent flow data for 9BS appear low relative to the historic data. Difficulty was encountered in measuring flows at 9BS during previous data collection efforts. Pumping operations resulted in fluctuations in water elevation on the downstream side of the flume, and only a few meaningful measurements were obtained. Recent conductivity and pH values were higher than the average values. Figure 6-10 presents the flow and conductivity data for 9BS.

The 9KT (Kellogg Tunnel Portal) flow data are also relatively low compared to historic data. Figure 6-11 presents historical flow and conductivity data for 9KT. Note that differences in flow rates are expected based on lower pump volumes associated with less vigorous dewatering efforts utilized in the 1980s.

Summing the three major flow contributors to the KT (9BS, 9LA, and 9PU) should provide a measure of the monitoring system effectiveness in measuring all flows. For December 1, 1998, when the pump system was inoperative, the total for 9BS and 9LA was 505 gpm. This compares very well to the 9KT flow of 532 gpm, providing a relative percent difference (RPD) of 5.2 percent. Note that the New Caledonia Workings historically add 1 to 2 percent of average 9KT flow. On November 13, 1998, the data do not compare as well. The total of 417 gpm versus the 9KT flow of 495.1 gpm provides an RPD of 17.1 percent. This larger difference could be the result of the flow at 9KT increasing or decreasing in response to the pumps cycling on or off. The difference may also be due to the accuracy of the flumes.

Supplement No. 1A – Conceptual Model Interim Data Summary for the 1998/1999 Monitoring Program (Appendix B) provides an updated summary of results for the monitoring program through April 14, 1999. Updated mass balances are provided in this document as well. Although 50 percent of zinc load and lime demand are unaccounted for at 9LA, this compares well with past data. The balances for flow, zinc load and lime demand demonstrate that the major tributaries (9PU, 9LA, 9BS) close well around 9KT.

Figure 6-1
Flow and Conductivity Data for 3 Level - Homestake Drift
Bunker Hill Mine Water Management

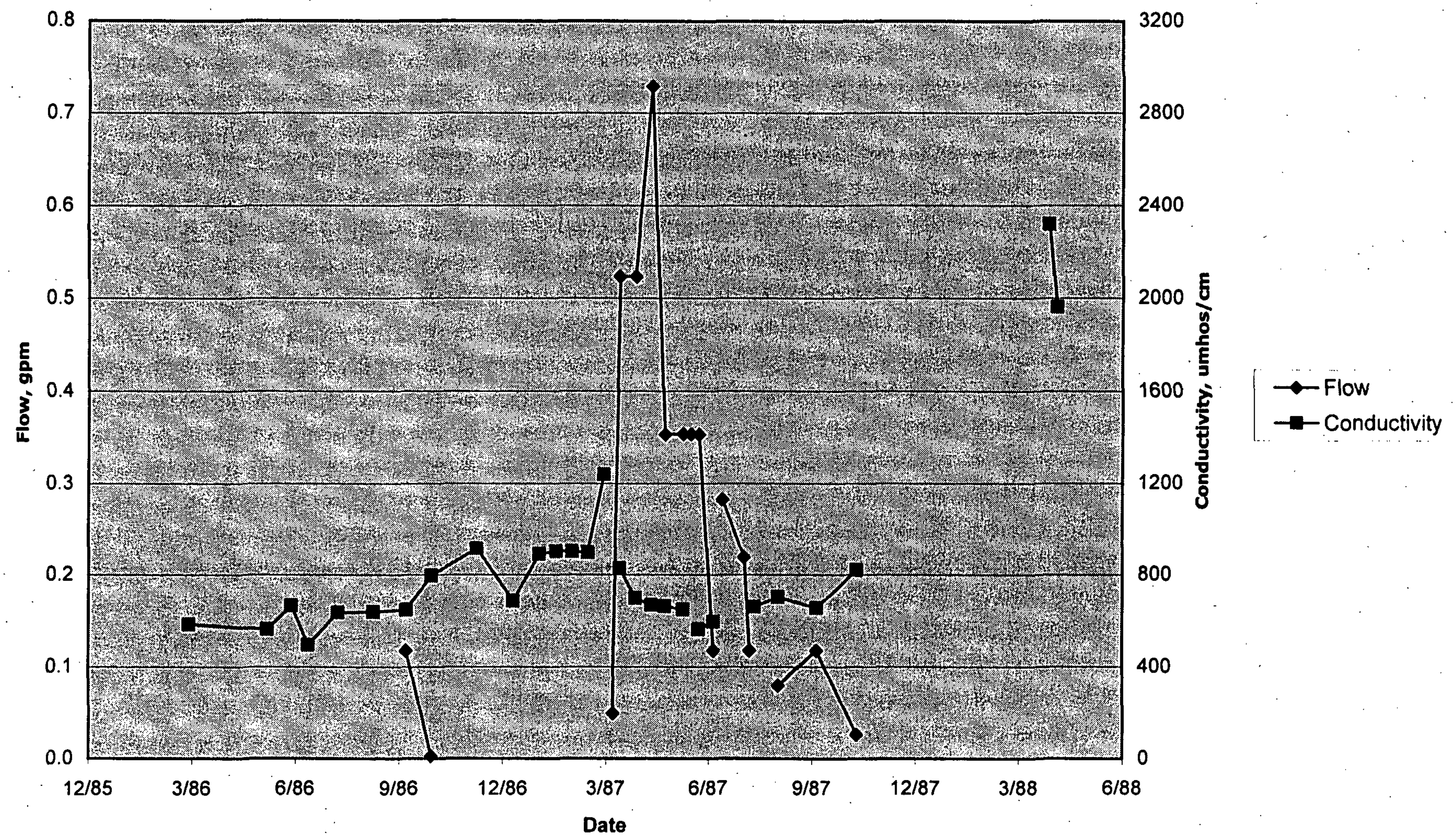


Figure 6-2
Flow and Conductivity Data for 5 Level - Williams Flume
Bunker Hill Mine Water Management

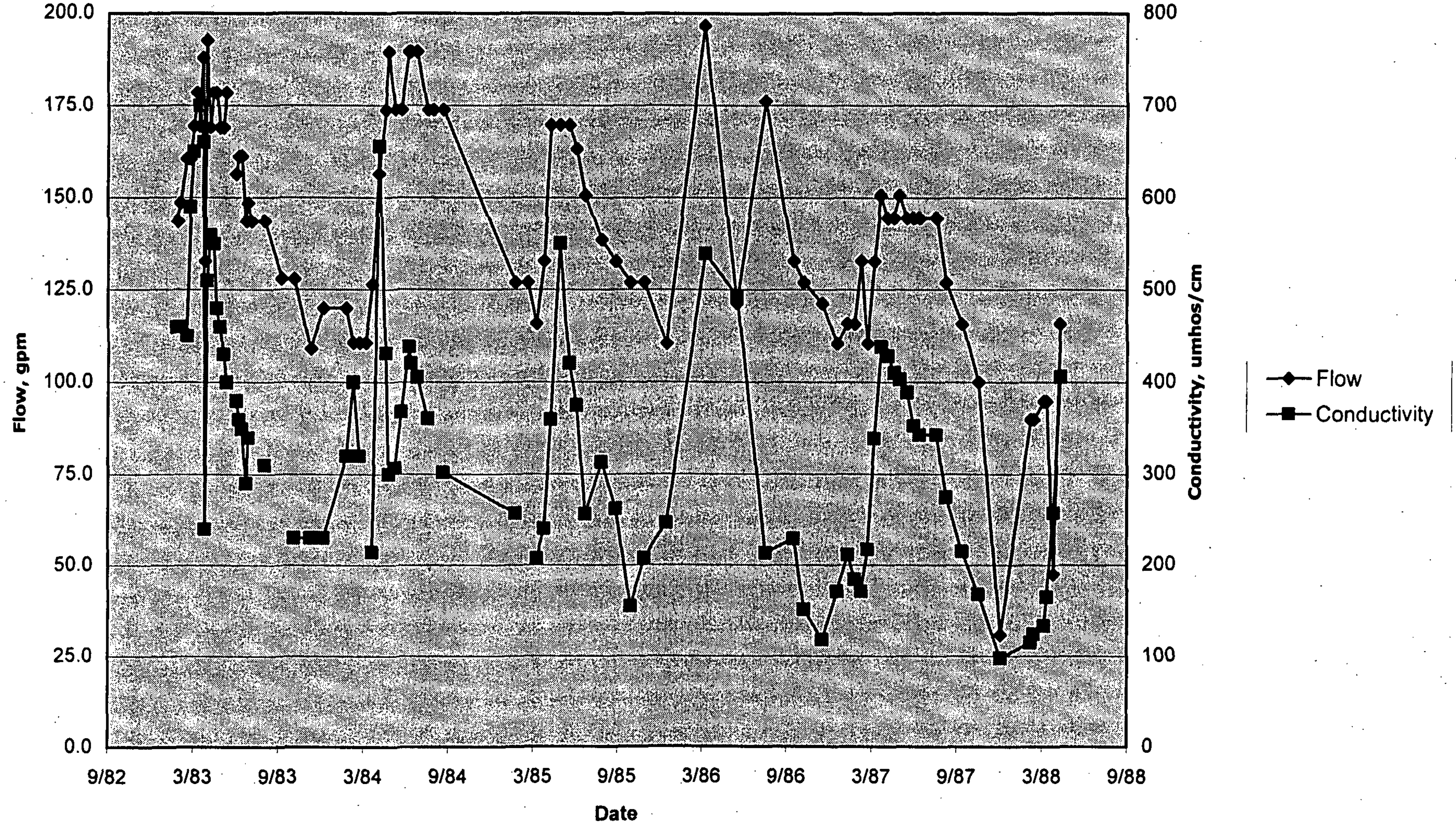


Figure 6-3
Flow and Conductivity Data for 5 Level - West Reed Flume
Bunker Hill Mine Water Management

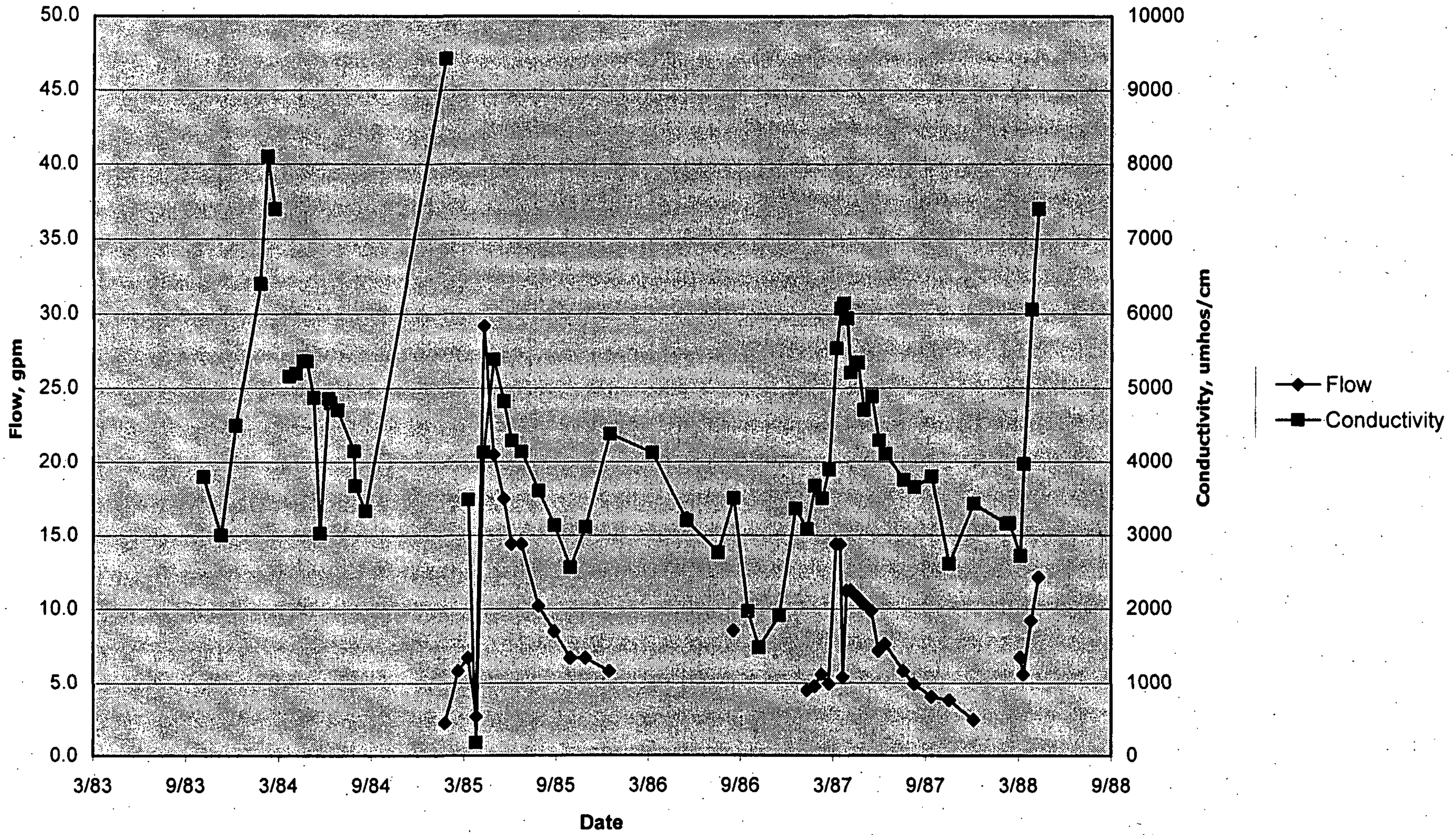


Figure 6-4
Flow and Conductivity Data for 5 Level - Becker Flume
Bunker Hill Mine Water Management

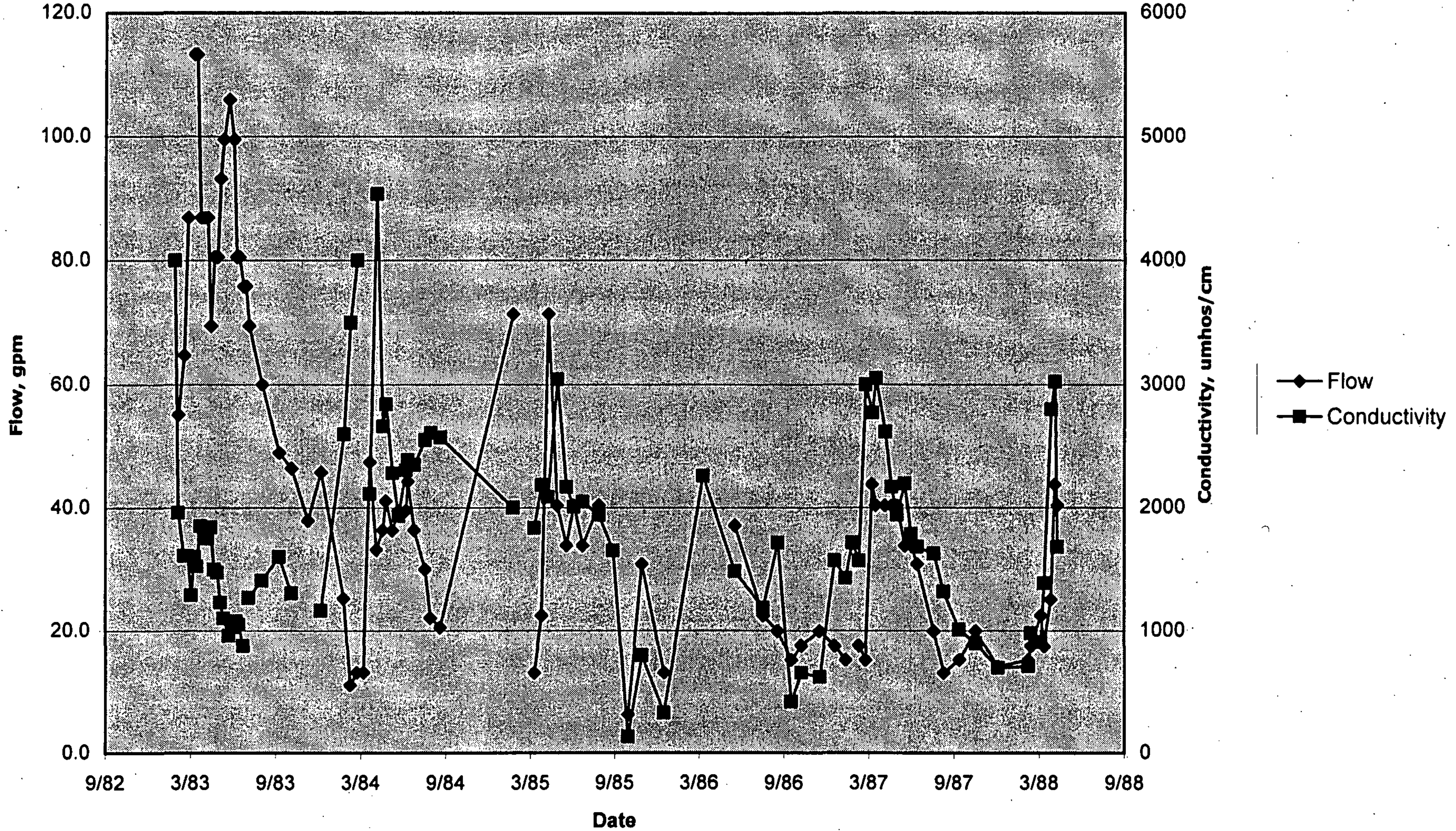


Figure 6-5
Flow and Conductivity Data for 9 Level - Bailey Ore Chute
Bunker Hill Mine Water Management

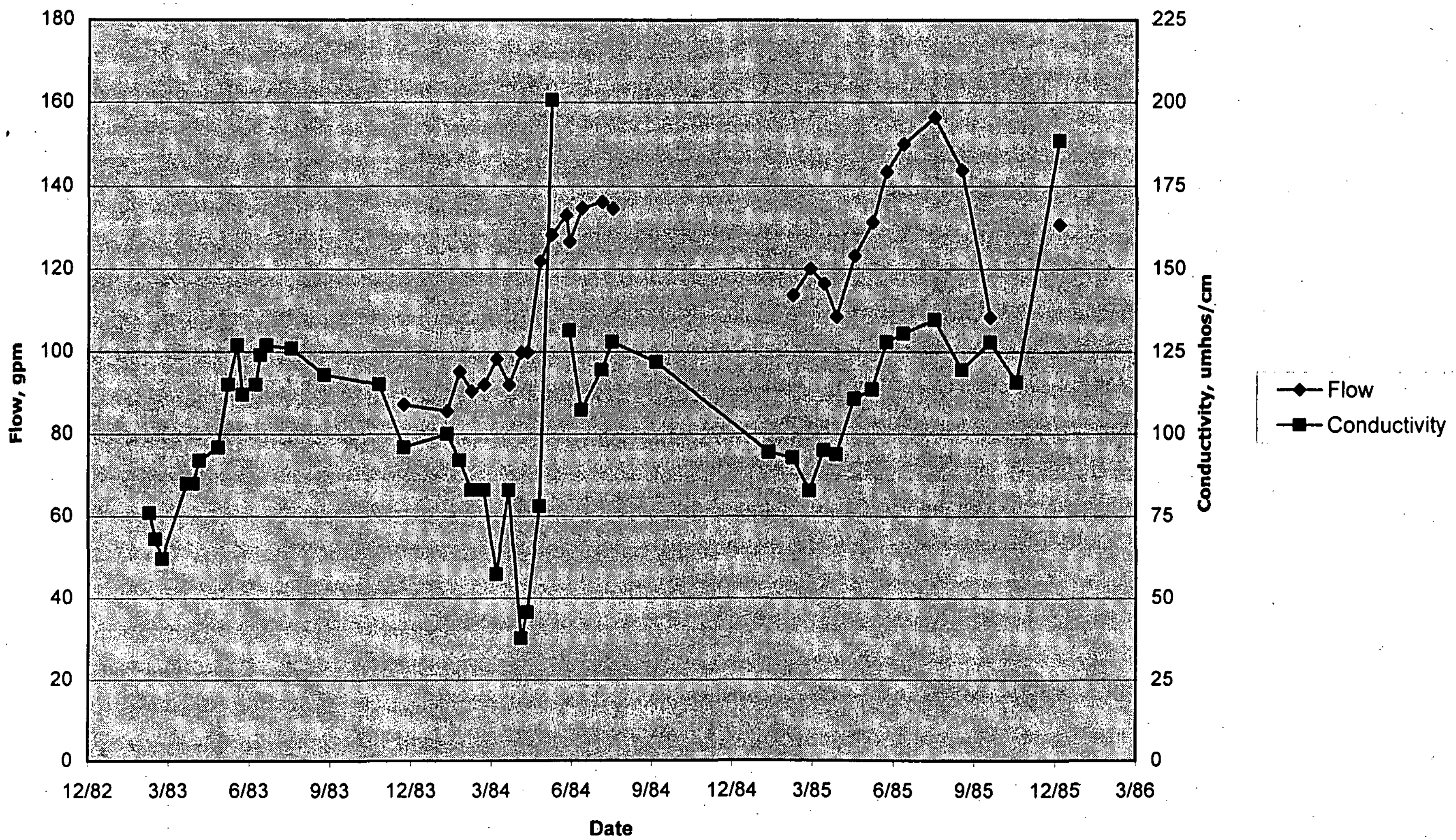


Figure 6-6
Flow and Conductivity Data for 9 Level - Cherry Raise
Bunker Hill Mine Water Management

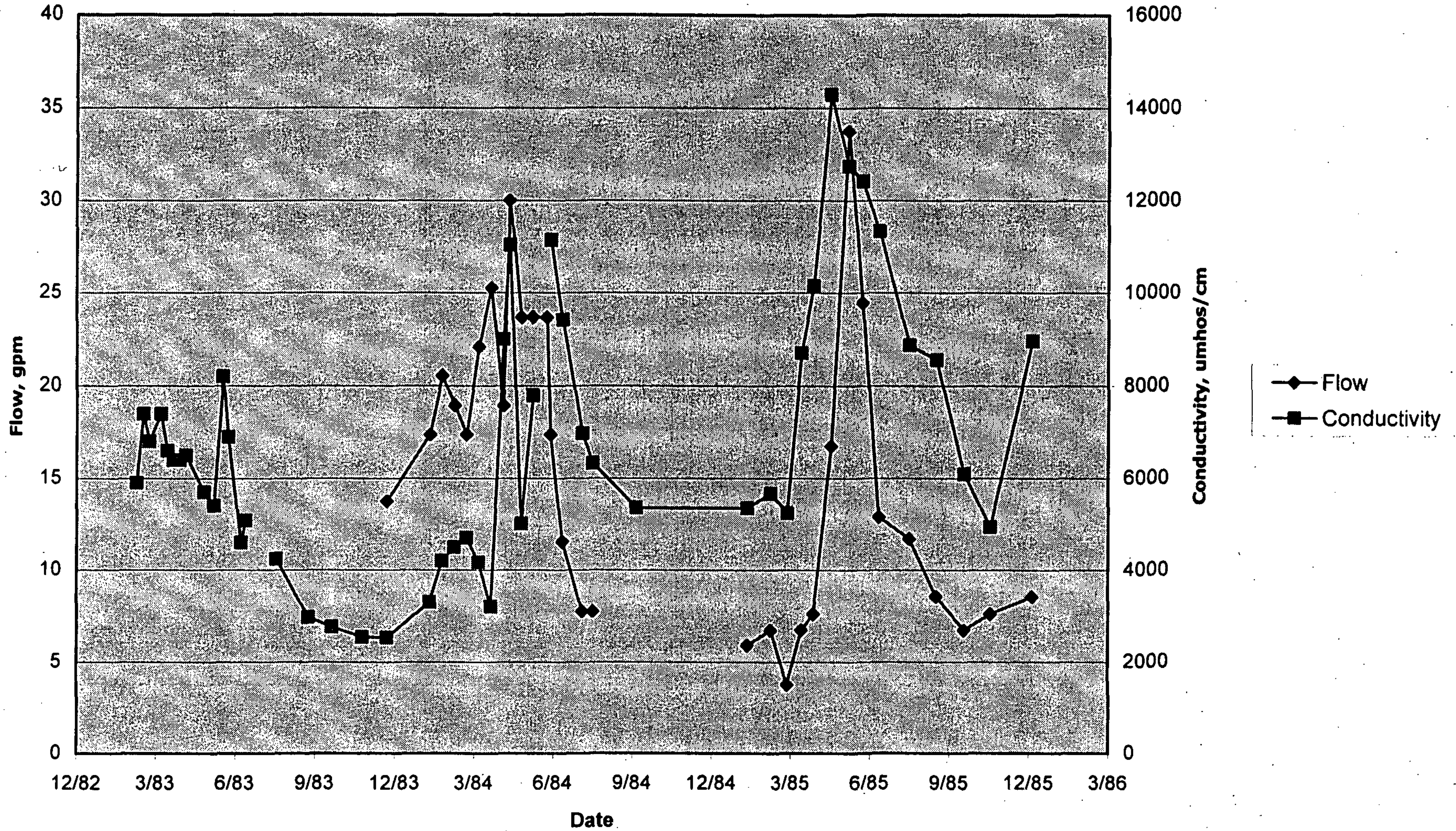


Figure 6-7
Flow and Conductivity Data for 9 Level - Stanly Crosscut
Bunker Hill Mine Water Management

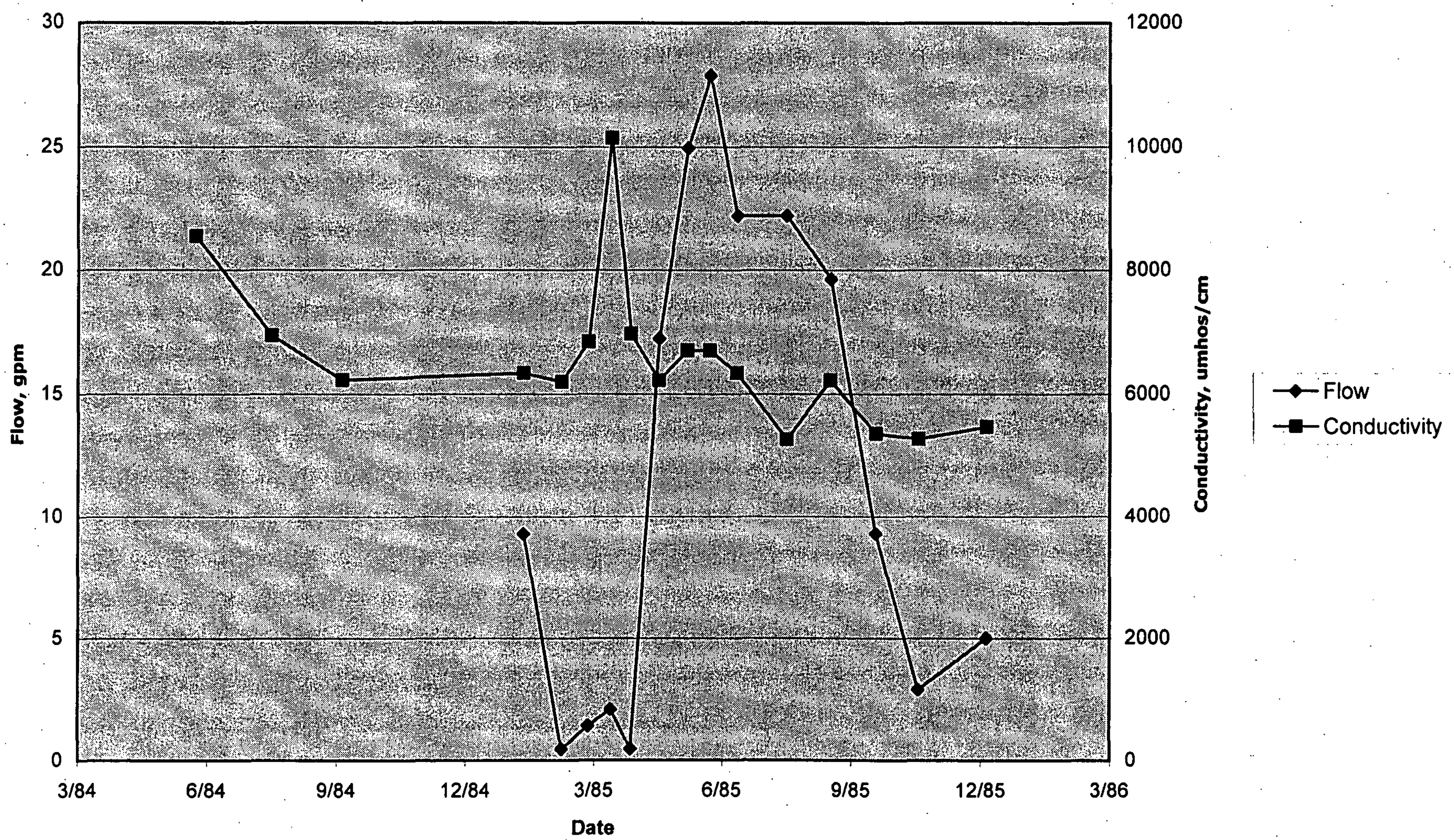


Figure 6-8
Flow and Conductivity Data for 9 Level - Stanly Ore Chute
Bunker Hill Mine Water Management

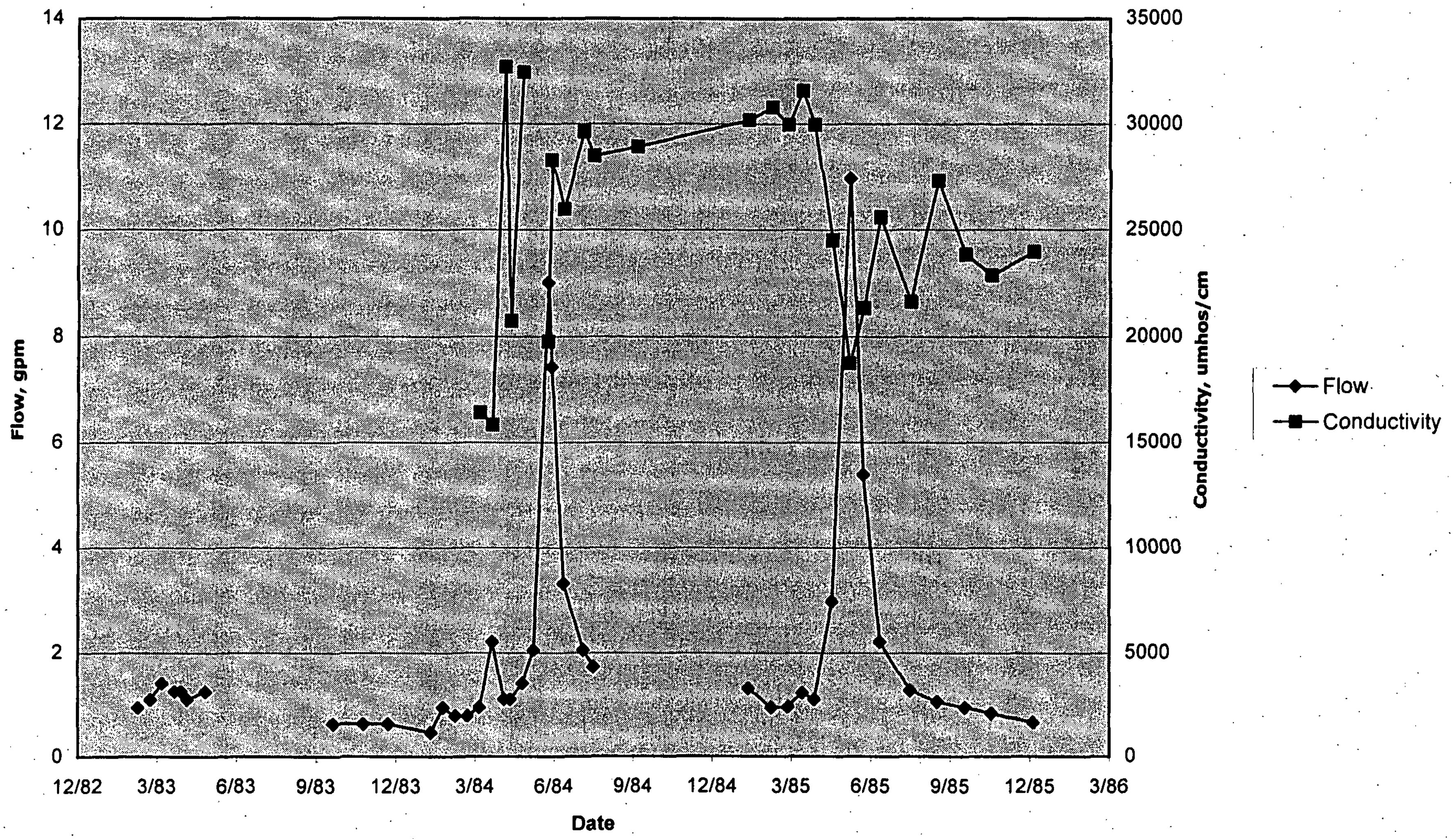


Figure 6-9
Flow and Conductivity Data for 9 Level - Loadout @ 9 Level
Bunker Hill Mine Water Management

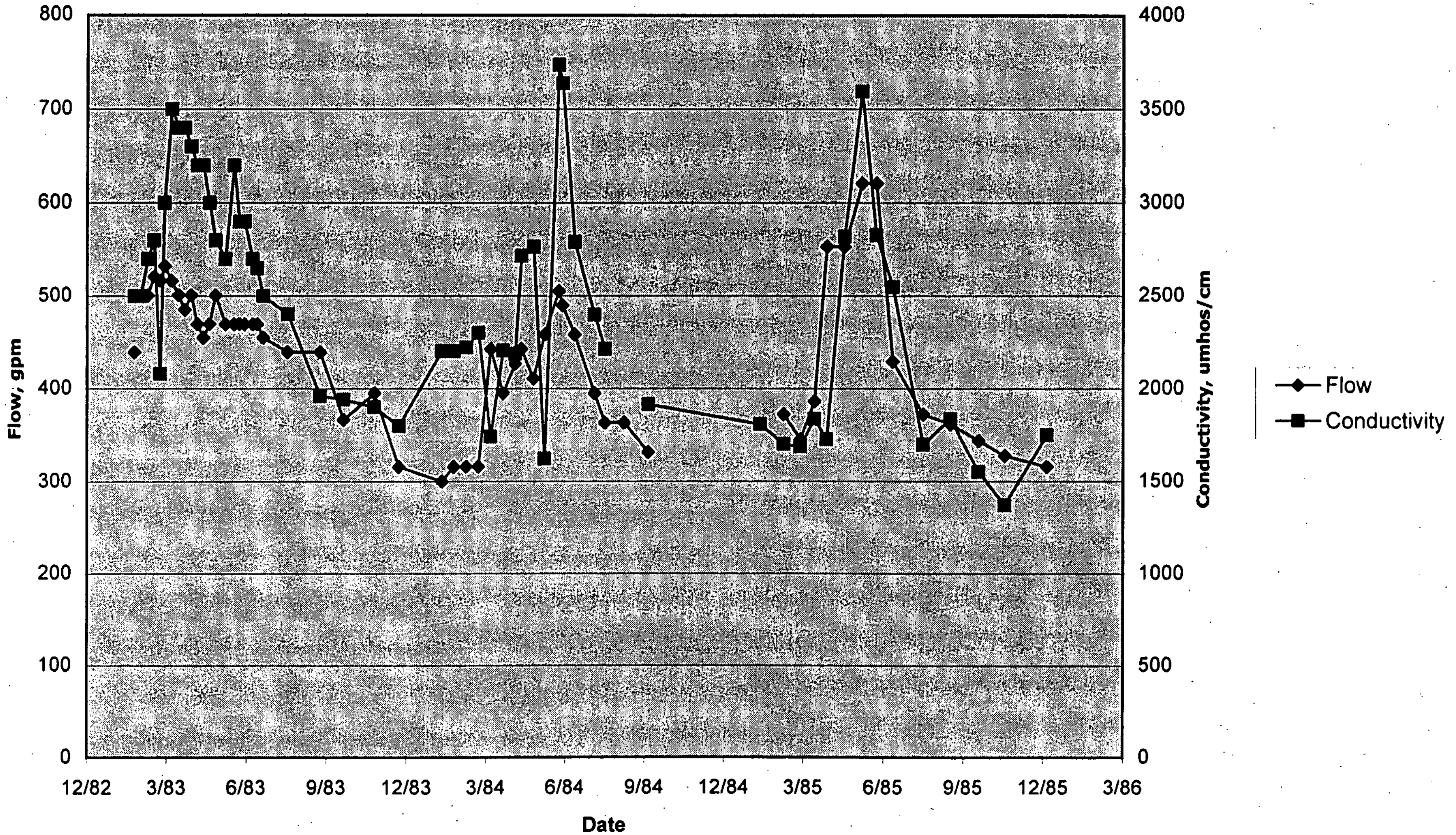


Figure 6-10
Flow and Conductivity Data for 9 Level - Barney Switch
Bunker Hill Mine Water Management

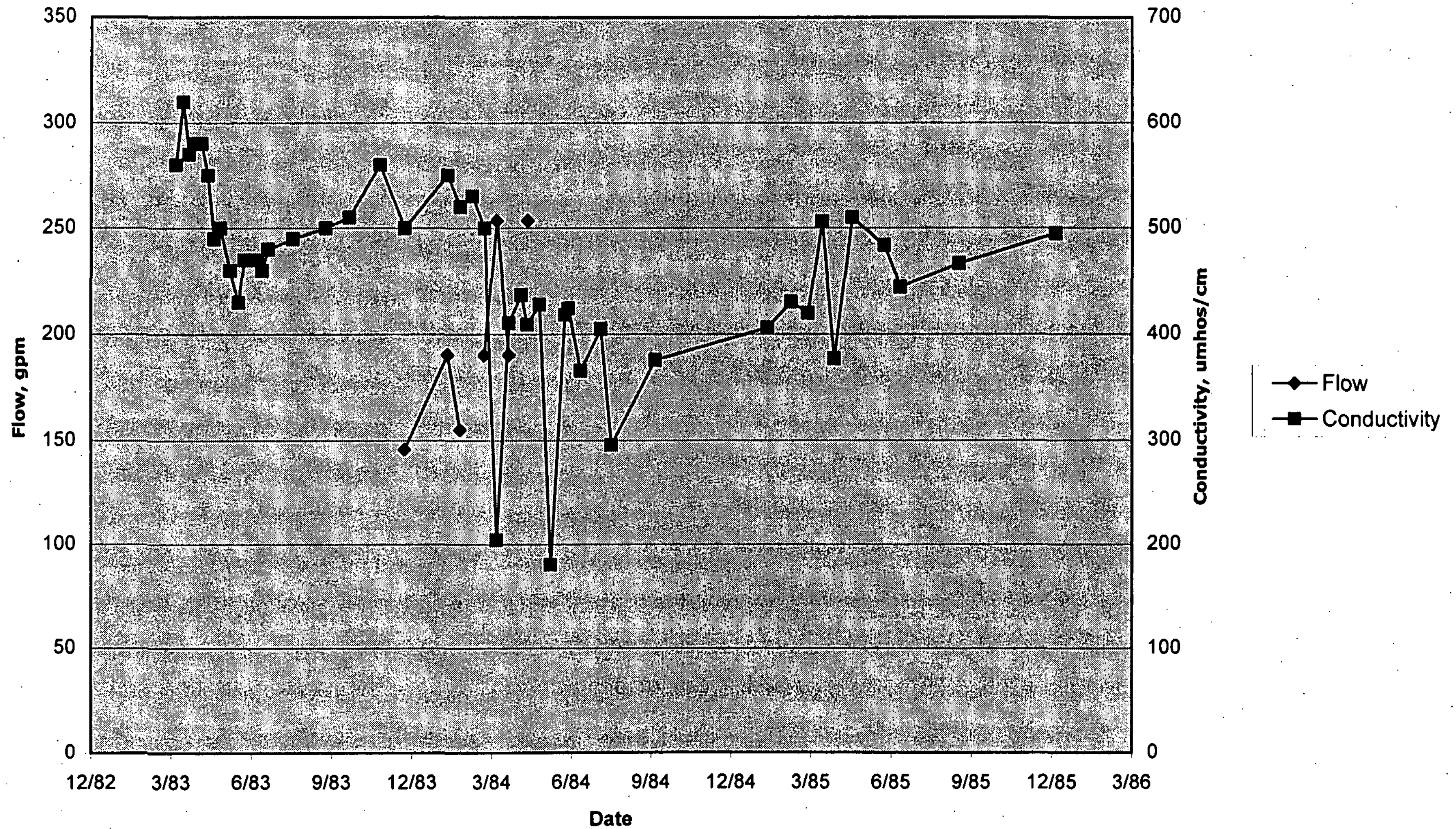
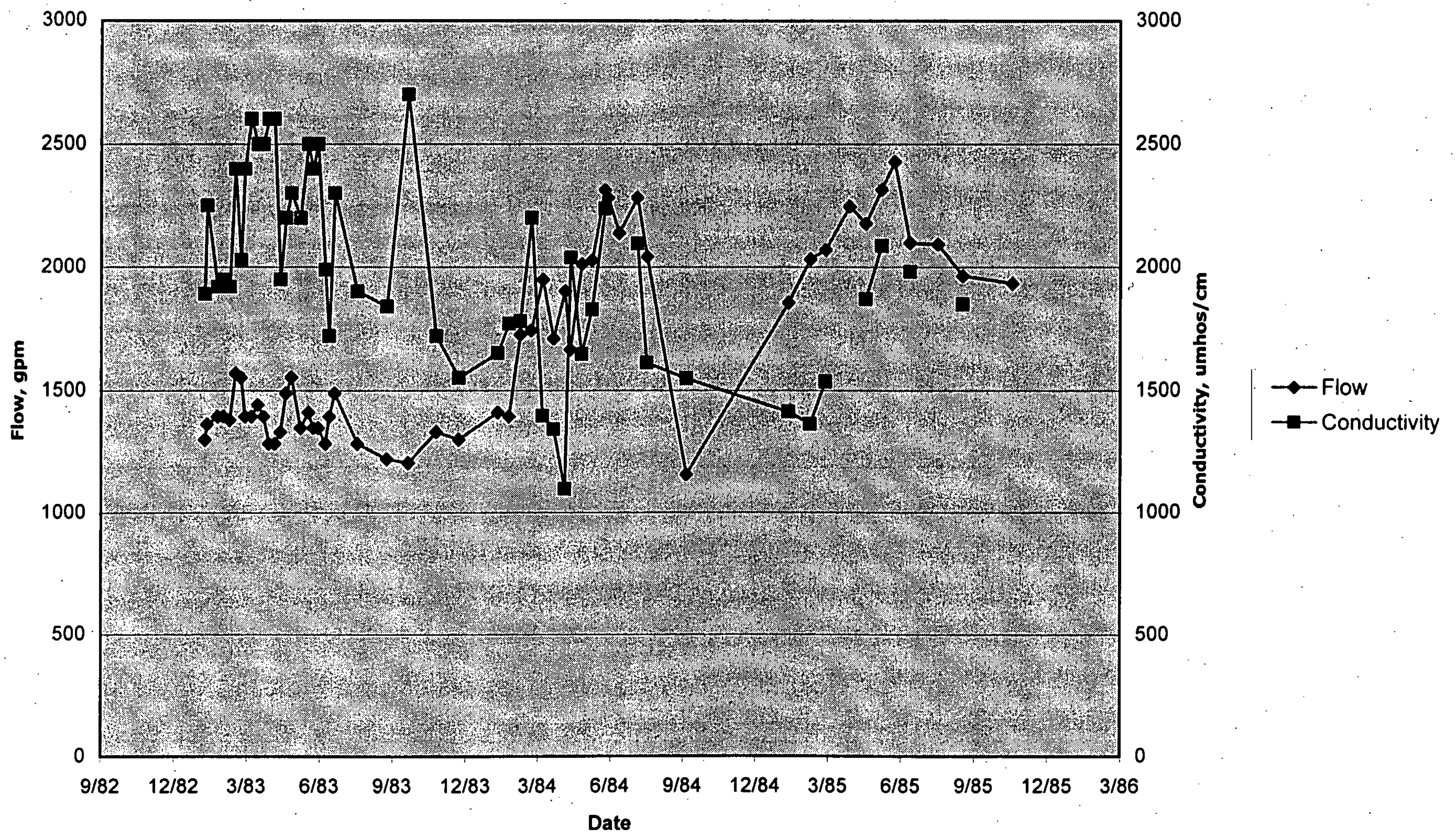


Figure 6-11
Flow and Conductivity Data for 9 Level - Kellogg Tunnel
Bunker Hill Mine Water Management



7.0 Potential for AMD Generation Mitigations

Several alternatives have been proposed throughout the various investigations conducted at the Bunker Hill Mine in an attempt to decrease the quantity of water flowing from the mine and ultimately improve the quality of the water. The most promising alternatives include decreasing the surface water inflow from the West Fork, South Fork, and Mainstem of Milo Creek, and decreasing the inflow from Deadwood Creek. Additional alternatives include dewatering faults in the vicinity of the mine and preventing recharge to the faults by grouting. A more thorough evaluation of mitigation measures is provided in the AMD Mitigation Technical Memorandum.

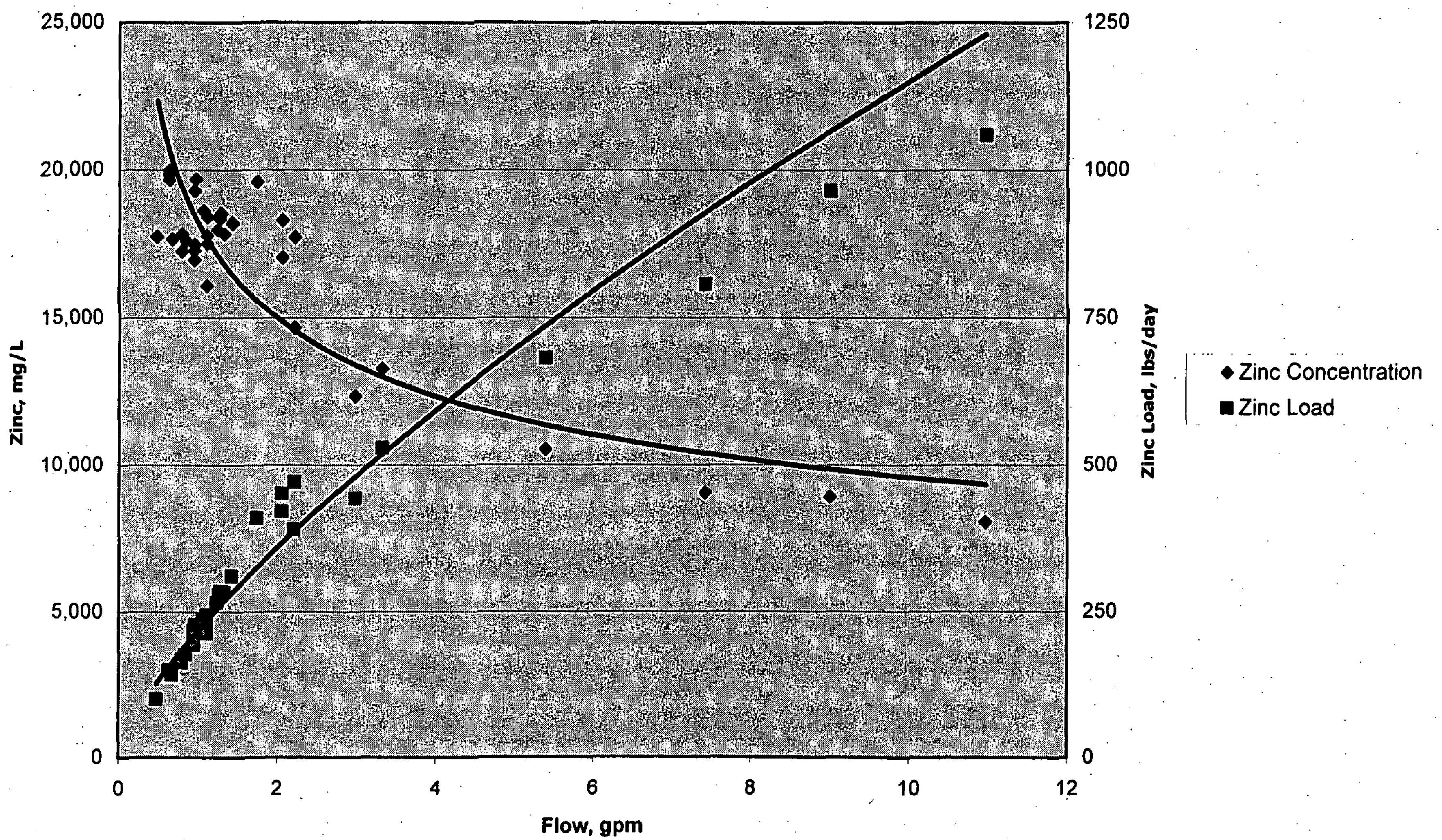
The majority of poor quality water originates in the pyrite-rich Flood-Stanly workings. The submerged workings also contain mine tailings that were used to backfill much of the stoped areas between levels in the mine. These tailings are ground-up pure pyrite occupying the submerged workings, and they are a source of the poor quality water at 9SO. However, due to the extent of the Bunker Hill Mine and the limited access to most areas, it is difficult to identify all sources of AMD generation: Only the major contributors can be identified at the present time. Figure 2 in Appendix A shows the magnitude of the mine workings from the cross sectional view.

Table 3 shows that with respect to the Milo discharge measured at 9LA (Loadout Area at 9 Level), the Flood-Stanly discharge measured at 5WR (West Reed), 9CR (Cherry Raise), 9SO (Stanly Ore Chute), and 9SX (Stanly Crosscut) constitutes about 60 percent of the zinc load and only 9 percent (38 gpm) of the hydraulic load. The remaining zinc load at 9LA is most likely from undetected Flood-Stanly discharge. These unidentified sources exist in areas of the mine with high pyrite content. Some of these areas do not represent measurable streams of flow. Using a proportional relationship, and assuming that the discrete Flood-Stanly monitoring locations represent the average zinc concentration in Flood-Stanly discharge, this remaining unidentified zinc load could be represented as an additional 26 gpm. Theoretically, the average zinc load measured at 9LA can be attributed to 64 gpm discharging from the Flood-Stanly workings. *Supplement No. 1A – Conceptual Model Interim Data Summary for the 1998/1999 Monitoring Program* in Appendix B provides a more recent summary of results for the monitoring program.

Figure 7-1 shows the relationship of flow and zinc concentration and load at 9SO, which originates in the Flood-Stanly workings. The approximate trend lines show that a reduction in flow from this area will result in an increase in concentration, but a decrease in the overall load. A similar relationship is evident at the other monitoring locations that measure Flood-Stanly discharge.

The current conceptual model of the mine suggests that attempts to divert surface water around the Flood-Stanly workings (that is, Guy Caving) may significantly reduce the inflow of water. Fault dewatering through the use of properly located drill holes may also reduce the inflow of water to the workings. The effectiveness of these and other potential mitigation measures will depend on how much water is diverted from the mine, but more importantly, how much of the theoretical 64 gpm will be diverted from flowing through the Flood-Stanly workings.

Figure 7-1
Flow vs. Zinc Concentration and Zinc Load for 9SO
Bunker Hill Mine Water Management



Additional study is needed to provide information on the relationship between general flow mitigation measures and their effectiveness at reducing flow to the Flood-Stanly workings.

8.0 Conclusions

Several conclusions can be formulated from the research and recent sampling efforts that are summarized in this conceptual model. Uncertainties exist with many of these conclusions because of the complexity of intra-mine flow. For the most part, these conclusions are consistent with those of past researchers. They are as follows:

- Acid and dissolved metals are produced through a complex series of interrelated chemical reactions. Acid generation can be expected from ore in the mine that is pyrite-rich. It is likely that the air and the humidity in the mine provide sufficient oxygen and water for the reactions to occur.
- Water inflow to the mine occurs from direct interception of surface water to the workings, recharge to the local groundwater system through faults and other hydrogeologic features, and recharge to the submerged workings from the local groundwater system and interconnected drifts.
- Intra-mine flow is complex and not fully understood. The 5 Level and 9 Level flow paths have been presented in the conceptual model based on previous research work and recent site visits. The majority of flow from the upper country is monitored at location 9LA.
- Surface water and groundwater interactions that were identified in this conceptual model include a variety of interception and recharge flow paths originating in the west, south, and mainstem forks of Milo Creek and in Deadwood Creek.
- The historical database indicates that the three biggest contributors of zinc load to the Kellogg Tunnel are 9SO, 9CR, and 9SX. Each of these locations monitors discharge from the pyrite-rich Flood-Stanly workings. The success of mitigation measures to decrease acid and metal loads from the mine will depend on their effectiveness in reducing water inflow to the Flood-Stanly workings.
- Preliminary data indicate that similar flow and water quality conditions exist when compared to historic (1983 through 1988) data for winter months. Additional monitoring is needed to provide information on the spring and summer conditions.

Table 6 presents the list of objectives for this conceptual model that were presented in Section 1. The list has been revised to include a column that discusses how the conclusions listed above meet the objectives, and provides the basis for recommendations presented in the following section.

TABLE 6
Status of Conceptual Model Objectives
Bunker Hill Mine Water Management

Presumptive Remedy Component	Objective	Status
Mitigation	Determine flow paths into mine	General flow paths are understood, additional work is needed to identify flow paths into Flood-Stanly workings.
	Identify changes in flow paths with respect to historic data	Current flow data are within historic winter values, additional monitoring is needed through spring and summer.
	Determine chemistry and location of acid production	Chemistry understood of AMD production. The Flood-Stanly ore body produces the majority of the acid and metal load.
Collection, Conveyance, and Storage	Determine flow paths within the mine	5 and 9 Level flow is understood relatively well. Flow on other levels is not fully understood. Flow within the Flood-Stanly ore body needs more evaluation.
	Identify maintenance requirements	Not conducted in conceptual model. These are known and described in the AMD Collection, Conveyance, and Storage Technical Memorandum.
	Determine storage capacity within mine	Not conducted in Conceptual Model, see Collection, Conveyance and Storage Technical Memorandum for estimates.
Treatment	Identify water quality and quantity coming from the mine	Included in Conceptual Model.
	Determine temporal variations in water quality and quantity	Included in historic data presented in Conceptual model, additional confirmation needed through spring and summer seasons.
Sludge Disposal	Related to objectives included in other components	See Sludge Disposal Technical Memorandum.

9.0 Recommendations

Several recommendations arise from a review of the material presented in the conceptual model. Additional recommendations may be developed as more data from the 1998/1999 sampling program become available.

First, the 1998/1999 sampling program should continue as scheduled through August 1999 to capture the spring and summer seasons. The data that are collected will provide valuable information on the current acid mine drainage relative to previous studies. Of particular interest is the relative contribution of acid from the Flood-Stanly workings, the change in total metal load due to modifications of the pumping system, and the seasonal variations in flow and water quality. Information from the sampling programs could affect the overall direction of the presumptive remedy for the site, and provide a technical basis for the selected remedy approach.

Second, additional information is needed to assess the effectiveness of potential AMD mitigation measures at the mine. Specifically, potential mitigation measures have to be investigated in terms of their ability to reduce inflow to the Flood-Stanly workings and other portions of the mine. Efforts should be concentrated on preventing water from getting into the zones of the mine with high pyrite content (such as the Flood-Stanly ore body) to reduce AMD generation significantly. It would be worthwhile to evaluate diversion of low flow streams near the zones of high pyrite content as well.

Fault dewatering through drill hole placement should be evaluated to assess the hydraulic effectiveness of reducing inflow to the Flood-Stanly workings. The relationship between surface water inflow and Flood-Stanly workings should be investigated in more detail to provide information on the effectiveness of diversions in reducing inflow to the Flood-Stanly workings. This investigation could be conducted through an additional phase of flume installation and sampling at appropriate locations. These locations could be used to conduct dye testing, and determine base flow conditions prior to diversion construction.

Efforts should be focused on diverting large recharge sources, such as diversion of Deadwood Creek. The effectiveness of a Deadwood Creek diversion should be evaluated with the objective of reducing the hydraulic load to the west side of the mine and preventing clean water from mixing with AMD in the mine. In-mine monitoring may be needed for the evaluation.

The information obtained from the recommendations would be used to assess the overall costs and benefits associated with AMD mitigation measures, and to substantiate the selection of mitigation measures in the future. The conceptual model will be updated periodically as new information becomes available.

10.0 Glossary of Frequently Used Mining Terms

Adit: A horizontal mine opening.

Bedding: Geologic arrangement of sedimentary rocks in strata.

Bedding Plane: The surface that separates ones stratum, layer, or bed of stratified rock from another. Individual layers of deposition found within sedimentary rock.

Chute: An inclined channel, as a trough, tube, or shaft, for conveying water, grain, coal, etc., to a lower level.

Conductivity: The conductivity of a solution is a measure of its ability to carry an electrical current, and varies both with the number and type of ions the solution contains.

Crosscut: A horizontal opening driven from a shaft and at right angles to the strike of a vein or rock formation.

Diamond Drill Hole: A small diameter boring whereby a rock core is extracted for the entire length of drilling and used in the exploration for ore.

Drift: An approximately horizontal passageway in underground mining. Openings in the mine that are driven to gain access to the ore body.

Floatation Tailings: The waste produced from the concentrating process of floatation. Floatation separation by chemical properties. The mineralized particles will adhere to air bubbles and rise to the top of the slurry. The waste product will sink to the bottom.

Flume: A widely used device for measuring the flow rate in open channels.

Grouting: The process of sealing off a water flow in rocks by forcing thin cement slurry, or other chemicals, into the crevices; usually done through a diamond drill hole.

Jig Tailings: The waste product from the concentrating process of jigging. Jigging relied on the specific gravity of the mineralization to separate the ore from the waste. Fines and any lighter ores such as zinc ores (sphalrite) were not effectively recoverable by jigging.

Level: Term used to differentiate the elevations in a mine. For example, the first adit may be called the 100 Level and next adit driven below may be called the 200 Level.

Mill: The plant where the mineralization and waste rock are separated. Mills are also called concentrators. The products of a mill are the concentrate and tailings.

Mine Waste: The rock that comes out of the mine that does not contain enough mineralization to be considered ore. Many times, the waste is non-mineralized from development drifts to reach the ore bodies.

Ore: The material from the mine that contained mineralization with a grade high enough to be profitable.

pH: The hydrogen ion concentration in terms of its negative logarithm.

Portal: The portion of an adit that is as the surface. Quite often, the portal is made of cement to keep it open.

Raise: A shaft excavated upward from below. An inclined opening from one level to another and used for accessing an ore body.

Shaft: A vertical or sloping passageway leading to the surface used for hoisting or lowering of men or materials as well as hoisting or ore or waste.

Stope: Any excavation made in a mine, especially from a steeply inclined vein, to remove the ore that had been rendered accessible by the shafts and drifts.

Tailings Pile: An uncontained pile of waste material from a mill. Generally, the tailings piles are composed of jig tailings and have a particle size of less than 0.5 inch.

Tailings Pond: A contained impoundment of waste material from a mill. The material is generally composed of floatation tailings and is deposited in the pond as a slurry. The pond's purpose was to allow the solids to be decanted from the slurry.

Upper Country: 9 Level and above.

Yellow Boy: Iron hydroxide ($Fe(OH)_3$) precipitate that forms as a result of ferric iron (Fe^{3+}) hydroxylation (i.e., ferric iron reacting with H_20 molecules). Iron hydroxide precipitated out of acidic water and accumulated within the flow paths of water within the mine.

Waste Pile: A pile of mine rock that did not meet the minimum grade for ore. May contain some mineralization or may not contain any mineralization. Mine waste generally has not been crushed and as such has a particle size that can be up to one foot or greater. The majority of the particles will be less than 1 foot in size.

Winze: An internal shaft within a mine.

Workings: Any mine excavation or operating areas.

11.0 References

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Appendix A

Figure 1—Location of Bunker Hill Mine
Figure 2—Cross-Sectional View of the Mine

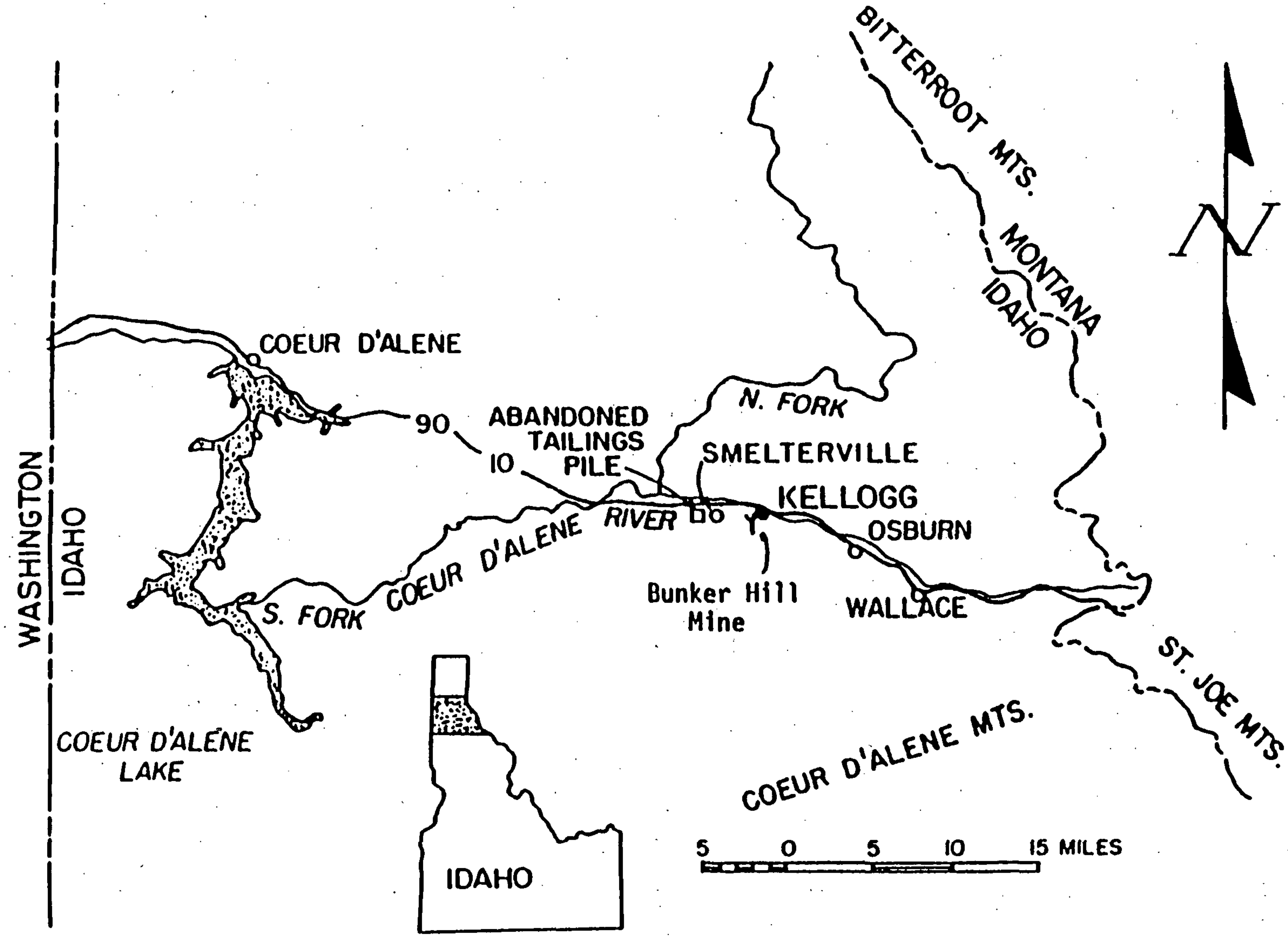

Figure 1. Map of part of Northern Idaho and adjacent areas showing the location of the Bunker Hill Mine (after Eckwright, 1982)

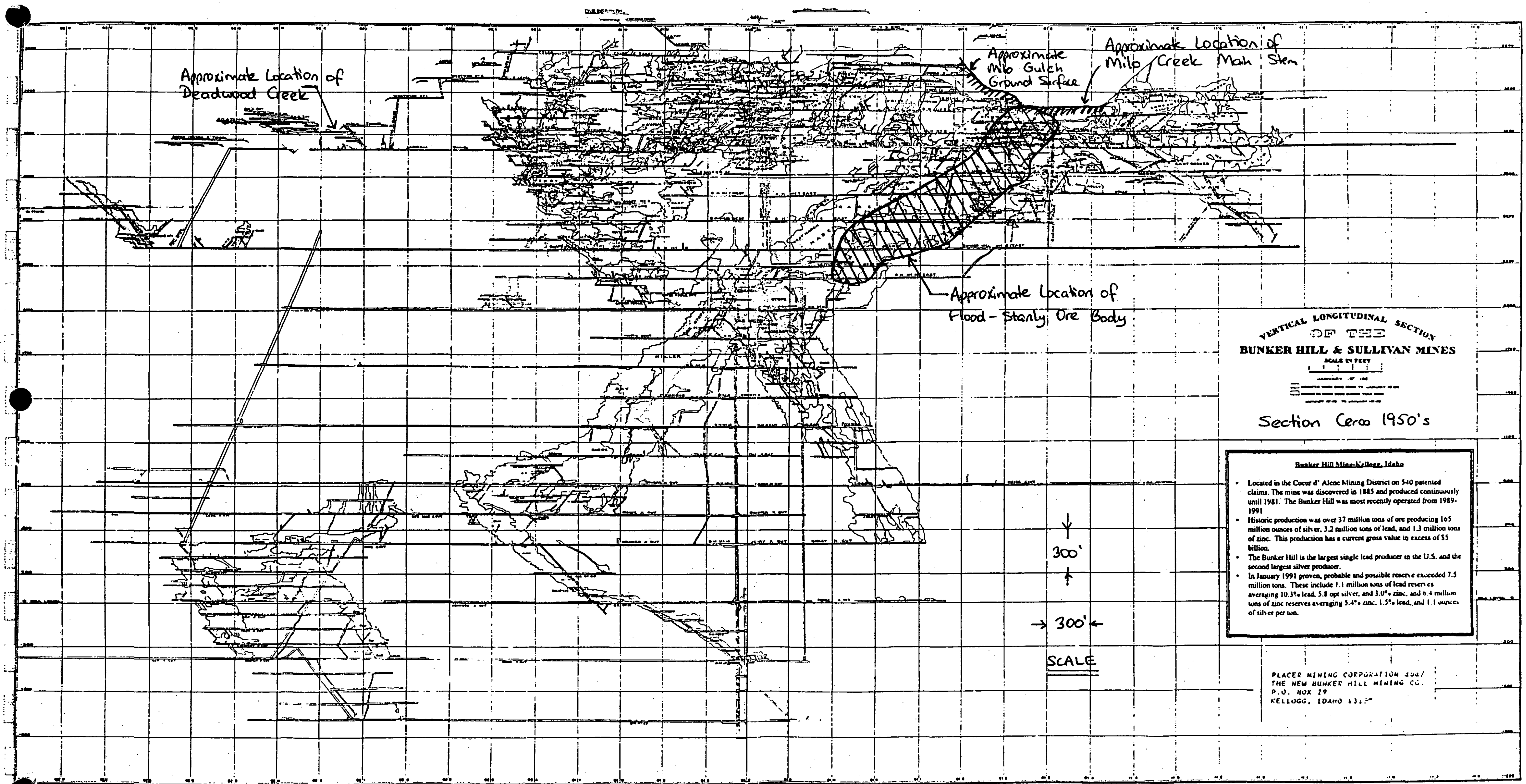

FIGURE 2
CROSS SECTIONAL VIEW OF THE MINE
Bunker Hill Mine Water Management
Conceptual Model

Appendix B

Supplement No. 1A—Conceptual Model Interim Data Summary for the 1998/1999 Monitoring Program

Supplement No. 1A—Conceptual Model Interim Data Summary for the 1998/1999 Monitoring Program—Bunker Hill Mine Water Management

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DATE: April 28, 1999

1.0 Introduction

This memorandum presents an interim data summary from the 1998/1999 AMD monitoring program that is currently being conducted at the Bunker Hill Mine. The monitoring program is part of the conceptual model component of the presumptive remedy for the Bunker Hill Mine Water Management project (RAC WA 021-RI-CO-105G). This data summary is being submitted as Supplement No. 1A to the conceptual model. The summary includes all data available from the 1998/1999 monitoring program through April 14, 1999.

1.1 Monitoring Program Purpose and Objectives

The purpose of the AMD monitoring program is to further the understanding of the mine water and to help refine the conceptual model and the presumptive remedy components that are being used to develop a long-term mine water management system. This is achieved through the assessment of current water quality and quantity conditions in mine water that is discharging from the Kellogg Tunnel, and in the tributary waters within the mine. Specific objectives of the monitoring program include the following:

- Support the identification and assessment of potential AMD generation mitigation measures, AMD collection, conveyance, and storage measures, and AMD treatment measures.
- Evaluate if current conditions have changed significantly since the last mine water evaluation conducted in the mid-1980s by John Riley and other University of Idaho researchers.

1.2 Memorandum Organization

This memorandum is organized to provide an update on the status of the monitoring program with respect to the above objectives. The format will be used in future interim data summaries presented as supplements to the conceptual model. The memorandum consists of the following subsections:

- Section 1—Introduction
- Section 2—Monitoring Program Modifications
- Section 3—Monitoring Results
- Section 4—Recommendations
- Section 5—References

2.0 Monitoring Program Modifications

The current AMD monitoring program includes fourteen monitoring locations. Twelve of these are Phase I locations that have been monitored since November 1998. Two Phase II locations were added to the monitoring program in February 1999; the Van Raise on 9 Level and Veral Dam on 11 Level. The Stanly Crosscut (9SX) was added to the analytical portion of the program; flow has been measured at 9SX since November. Four 'spot sample' locations have been included to refine the conceptual model. These locations consist of the Discovery Cut on 1 Level, Buckeye Adit on 2 Level, Utz on 3 Level, and the 7 Level Dam.

Flow measurement, sample collection, field measurement, and sample analysis protocols have remained the same since the beginning of the monitoring program.

3.0 Monitoring Results

The results of the monitoring program are presented in terms of mine water flow and quality. Zinc and lime demand are used as indicator parameters of water quality. Mass balances for recent sampling events are conducted to assess the completeness of the monitoring program. Summaries of all data collected to date are being maintained in Excel spreadsheet format and are available.

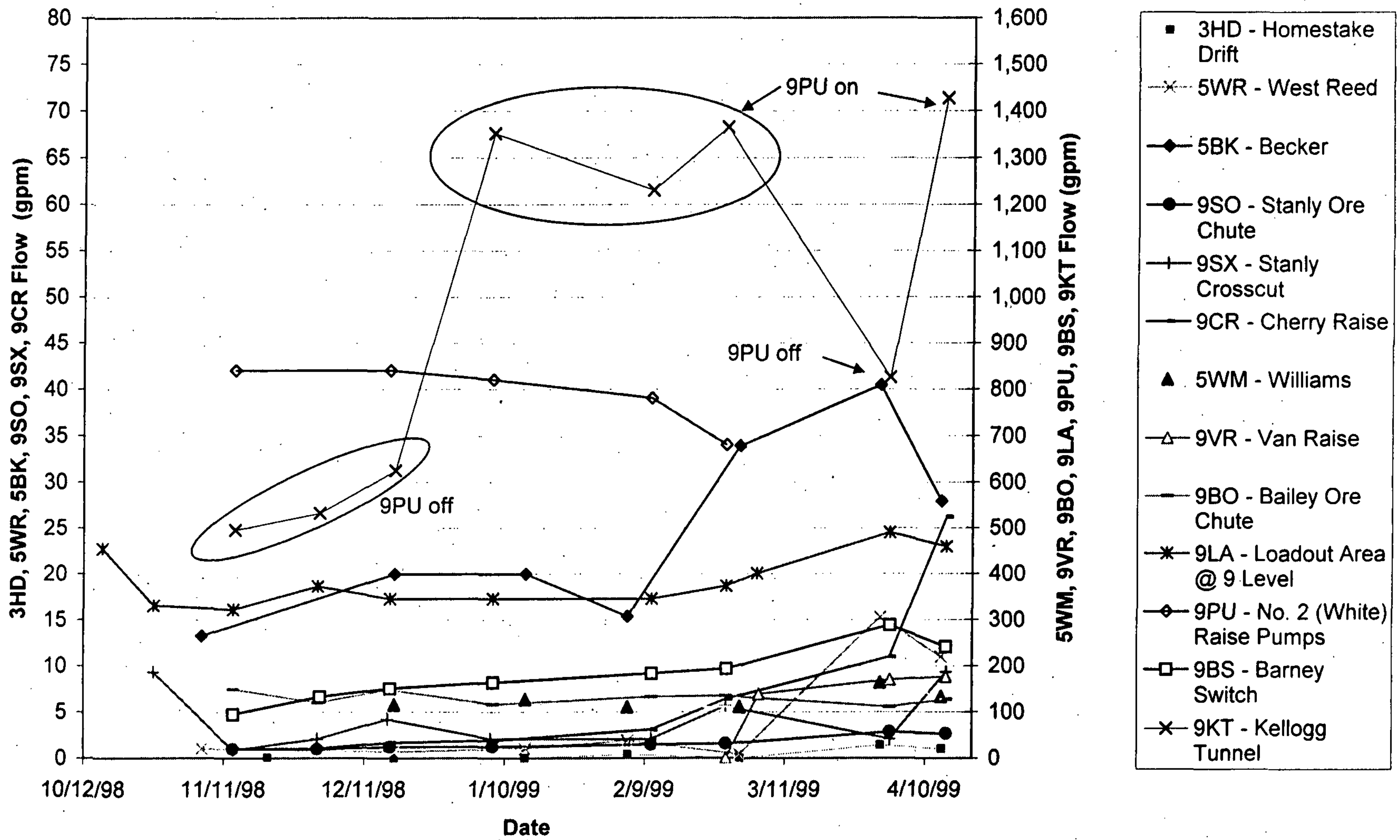
Comparisons to past data collected by John Riley and others in the 1980s are not included in this memorandum. The previous interim data summary (CH2M HILL, 1999) concluded that there was close agreement between historic and present data sets during the winter months. Although flows have started to rise in most locations, the comparison to historic data will be more useful once peak mine water flows are observed. It is expected that comparison to historic data will be presented in the next data summary memorandum.

3.1 Flow

A summary of flow data for each monitoring location is presented in Figure 1. The figure shows that all monitoring locations exhibit an increase in flow in early March.

As of April 14, 1999, some locations exhibit a decrease in flow while others continue to rise. These changing flows suggest that snowmelt began in early March, and cooler temperatures in April decreased snowmelt. Monitoring locations that measure flow from sources

Figure 1
Summary of AMD Flow Data
Bunker Hill Mine Water Management



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hydraulically connected to surface water and snowmelt infiltration (5WR, 5BK, 5WM) exhibit an increase in flow in early March. Other monitoring locations that are not directly connected to surface water and snowmelt infiltration exhibit a lag time of approximately 1 month, and flows pick up in early April.

The most dramatic increase is demonstrated at the West Reed Flume (5WR) and the Becker Flume (5BK). The current conceptual model suggests that these flumes are hydraulically connected to surface water infiltration through Homestake Drift (3HD) and Utz on 3 Level. A dramatic increase is also observed at 9CR and 9SX in early April, with a lag time of about 1 month after high flows were observed at 5WR and 5BK.

The figure presents flow data from the Kellogg Tunnel (9KT) during both pumping (9PU on) and non-pumping (9PU off) scenarios. Instantaneous data from 9KT varies widely due to 9PU cycling on and off. In addition, travel time for flow out the Kellogg Tunnel (approximately 3 hours) makes it difficult to know when the flow at 9KT represents the actual flow condition in the mine. For example, 9PU may be flowing but 9KT may only be measuring the rising portion of the hydrograph. The varying flows pumped by No. 2 Raise Pumps (9PU) may be due to wood and other debris clogging the screens where the pumps are located just below 11 Level.

3.2 Zinc Concentration and Zinc Load

Figure 2 shows the total zinc concentration (log scale) measured at each monitoring location. The zinc data is not as current as the flow data due to the time required for laboratory analysis and data validation. The figure shows that water from the Stanly Ore Chute (9SO) had the highest concentration of zinc at 1.6 to 2 percent by weight (16,000,000 to 20,000,000 μg/L) until early March. The zinc concentration reported for 9SO on February 26, 1999 is suspect due to laboratory dilution procedures, and is therefore not included in this data summary.

The Stanly Crosscut (9SX), recently included in the analytical program, appears to have the second highest zinc concentration at 0.1 percent to 0.5 percent. The Cherry Raise (9CR) and 5WR also exhibit high zinc concentrations at about 0.1 percent. The zinc concentration in the submerged workings at 9PU is consistently higher than the Williams Flume (5WM), the Barney Switch (9BS), and the Bailey Ore Chute (9BO).

Zinc loads can be estimated from the flow and zinc concentration data. Figure 3 presents zinc loads for all monitoring locations. The figure demonstrates that the majority of zinc load originates from the upper country workings and is measured at the Loadout Area (9LA). Zinc load at 9LA for the 2/10/99 event was 1,012 pounds per day (lb/day). Zinc load at 9KT is skewed because flows from both pumping and non-pumping scenarios were used in the load calculation. Other big contributors of zinc load include 9SO and the submerged workings at 9PU, each loading approximately 300 lb/day during winter base flow conditions. 9VR and 9SX each contribute about 100 lb/day.

A decrease is observed in zinc loading at 5WR due to the combined effect of lower flows and zinc concentrations observed in early March. Similarly, an increase in zinc loading is observed at 9CR due to higher flow and zinc concentration.

Figure 2
Summary of Analytical Data for Total Zinc
Bunker Hill Mine Water Management

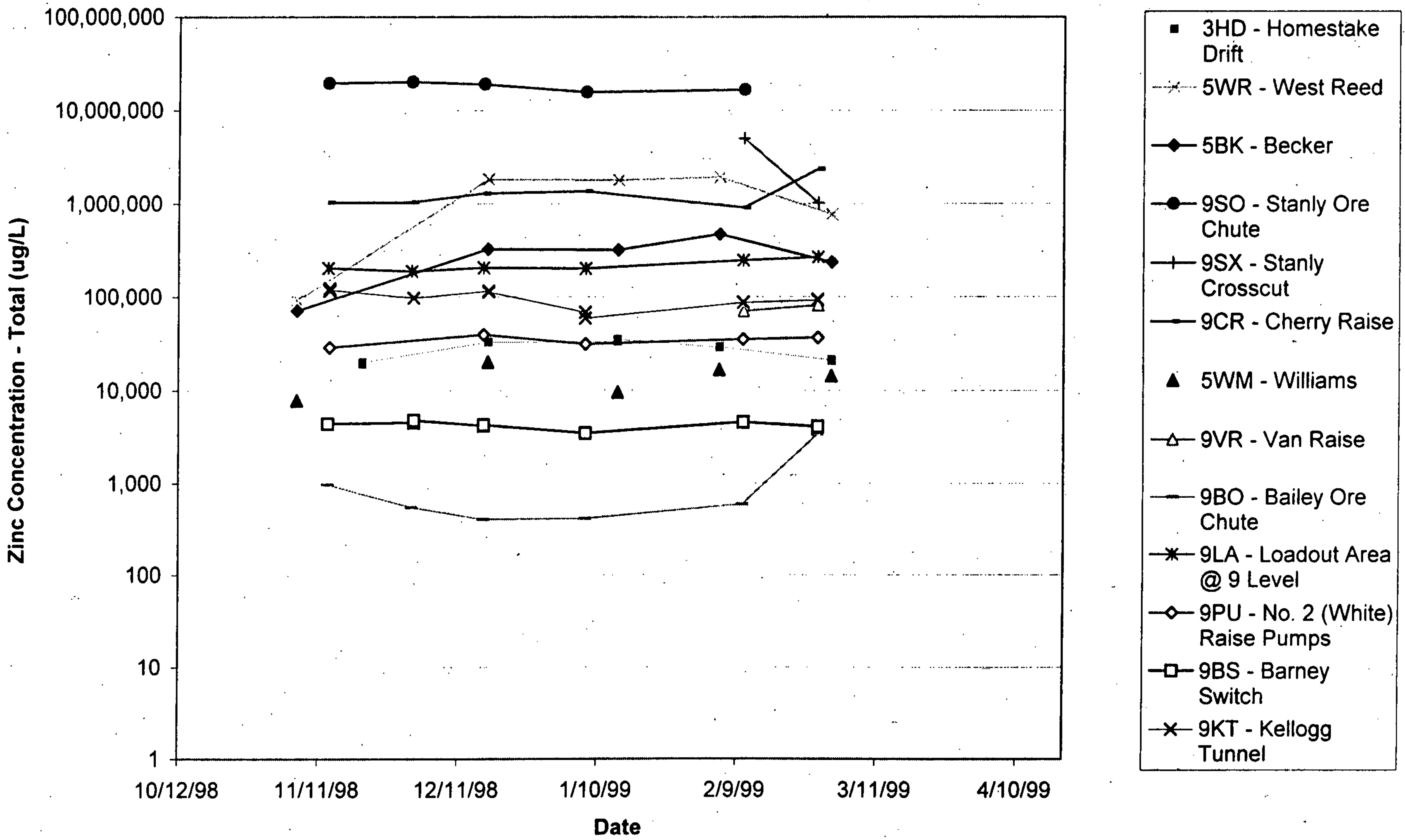

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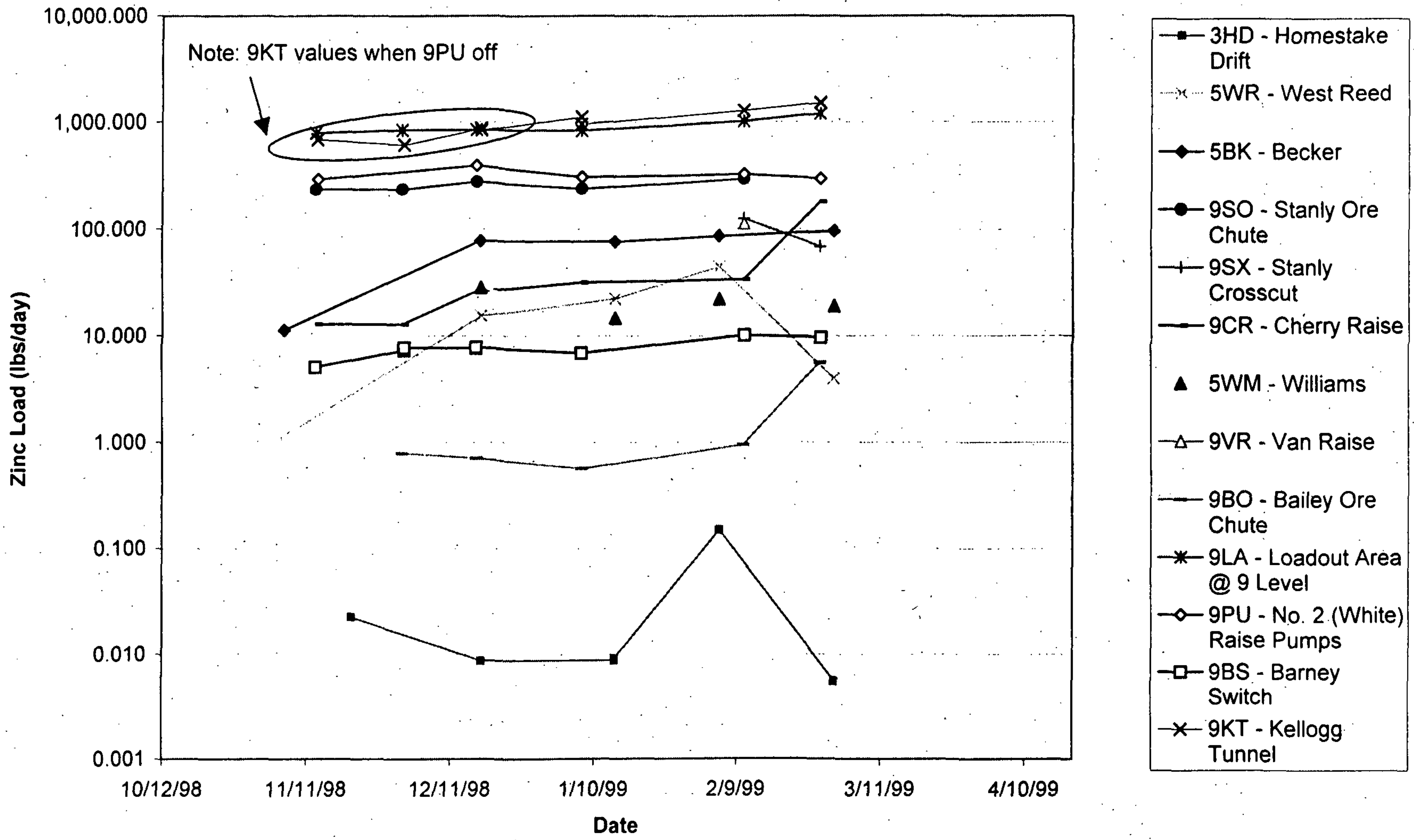
Figure 3
Summary of Zinc Load
Bunker Hill Mine Water Management



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3.3 Lime Demand and Lime Demand Load

Analytical data for lime demand is presented in Figure 4. 9SO has the highest lime demand of all the monitoring locations at 1,340 lb/1,000 gallons. Lime demand exhibits a decreasing trend at 9SO. Other locations with high lime demand include 5WR, 9CR, and 9SX. The reason for the fluctuation observed for 5WR is not known.

Lime demand load is presented in Figure 5. The figure shows that 9PU contributes the majority of lime demand load measured at 9KT (again, 9KT is low during the first three data points due to 9PU being off). 9LA accounts for about 5,400 lb/day of lime demand load, and has been steadily increasing due to increasing flow and lime demand.

3.4 Mass Balances

Mass balances were conducted on selected monitoring events to determine the closure within the current monitoring network for flow, zinc load, and lime demand load. Data from two events was used to conduct the balances: February 5 and 10, and February 26 and March 1 (two days of field work are required for each monitoring event).

February 5 and 10, 1999 Monitoring Event

Figure 6 presents the balances for flow, zinc load, and lime demand load at each location. Closure is expected within three flow loops ending at 9VR, 9LA, and 9KT. For the first loop, 5BK and 5WM provide about 93 percent, 95 percent, and 98 percent of the flow, zinc load, and lime demand load, respectively, at 9VR. For the second loop, 9VR, 9CR, 9BO, 9SO, and 9SX account for about 80 percent, 56 percent, and 51 percent of the flow, zinc load, and lime demand load, respectively, at 9LA. The majority of flow originates from 9VR and 9BO, while the majority of zinc load and lime demand load originates from 9SO and 9SX. Finally, the major tributaries (9LA, 9PU, and 9BS) account for 106 percent, 106 percent, and 118 percent of flow, zinc load, and lime demand load at 9KT. The majority of flow and zinc load originates from 9LA, while the majority of lime demand load originates from the submerged workings at 9PU.

The balances demonstrate that the major tributaries close well around 9KT. The new monitoring location, 9VR, also closes well with respect to its tributaries. 9VR was added to the monitoring network in an effort to tighten closure at 9LA. Data from this event shows that closure at 9LA has improved slightly from the mass balances presented in the Interim Data Summary (CH2M HILL, 1999), but a large portion of zinc load and lime demand load is not accounted for in tributaries currently being monitored.

February 26 and March 1, 1999 Monitoring Event

Figure 7 presents the balances for the February 26 and March 1 event. Flow, zinc load, and lime demand load at 5BK and 5WM account for 104 percent, 85 percent, and 97 percent, respectively, at 9VR. Tributaries to 9LA account for 77 percent, and 52 percent of flow, and lime demand load. Zinc load was not calculated for this event due to suspect zinc concentrations reported at 9SO. Major tributaries to 9KT account for 91 percent, 99 percent, and 119 percent of flow, zinc load, and lime demand load. The large contributors of flow and lime demand load for this event are similar to the previous sampling event discussed above.

Figure 4
Summary of Analytical Data for Lime Demand
Bunker Hill Mine Water Management

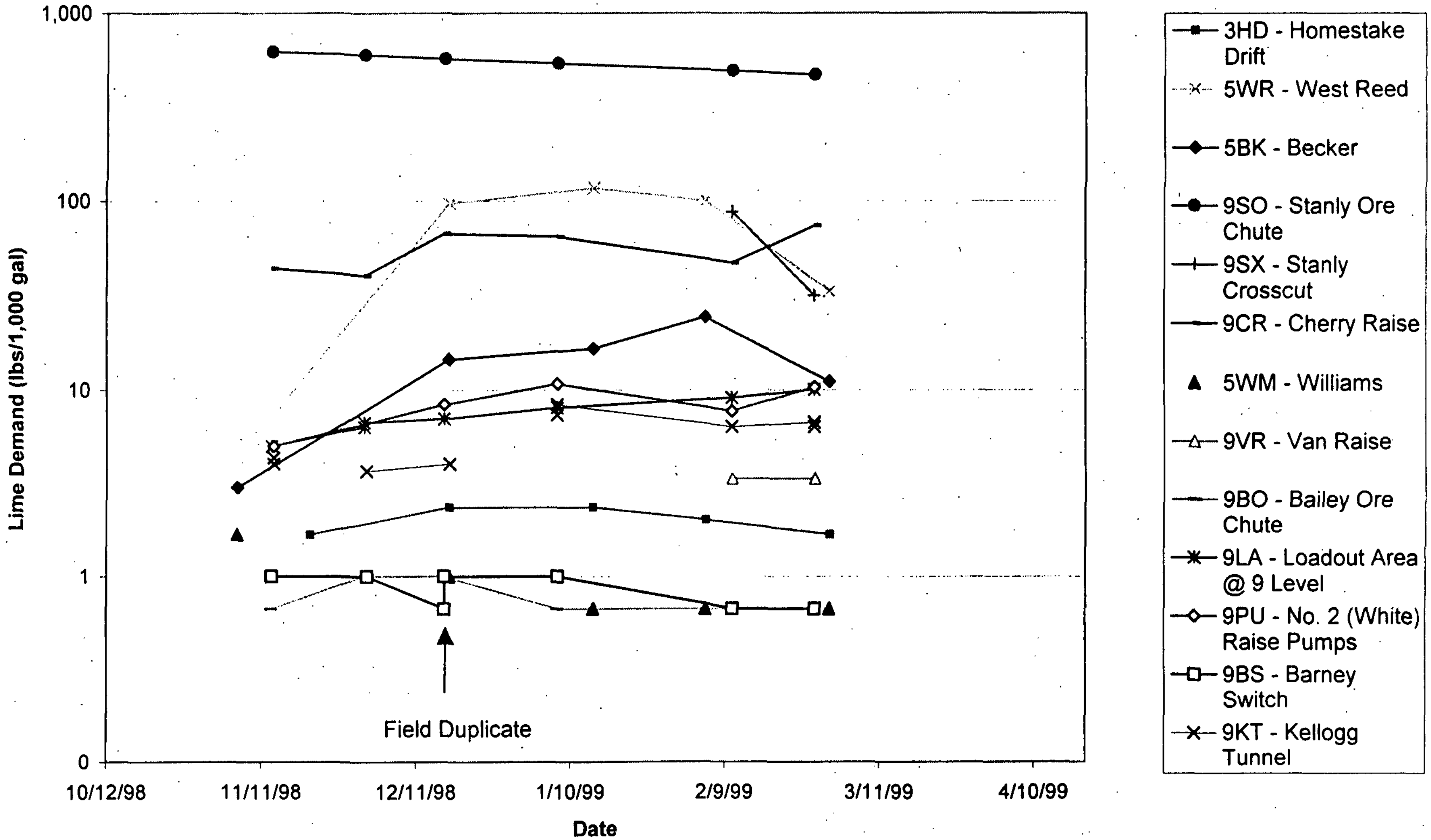

Figure 5
Summary of Lime Demand Load
Bunker Hill Mine Water Management

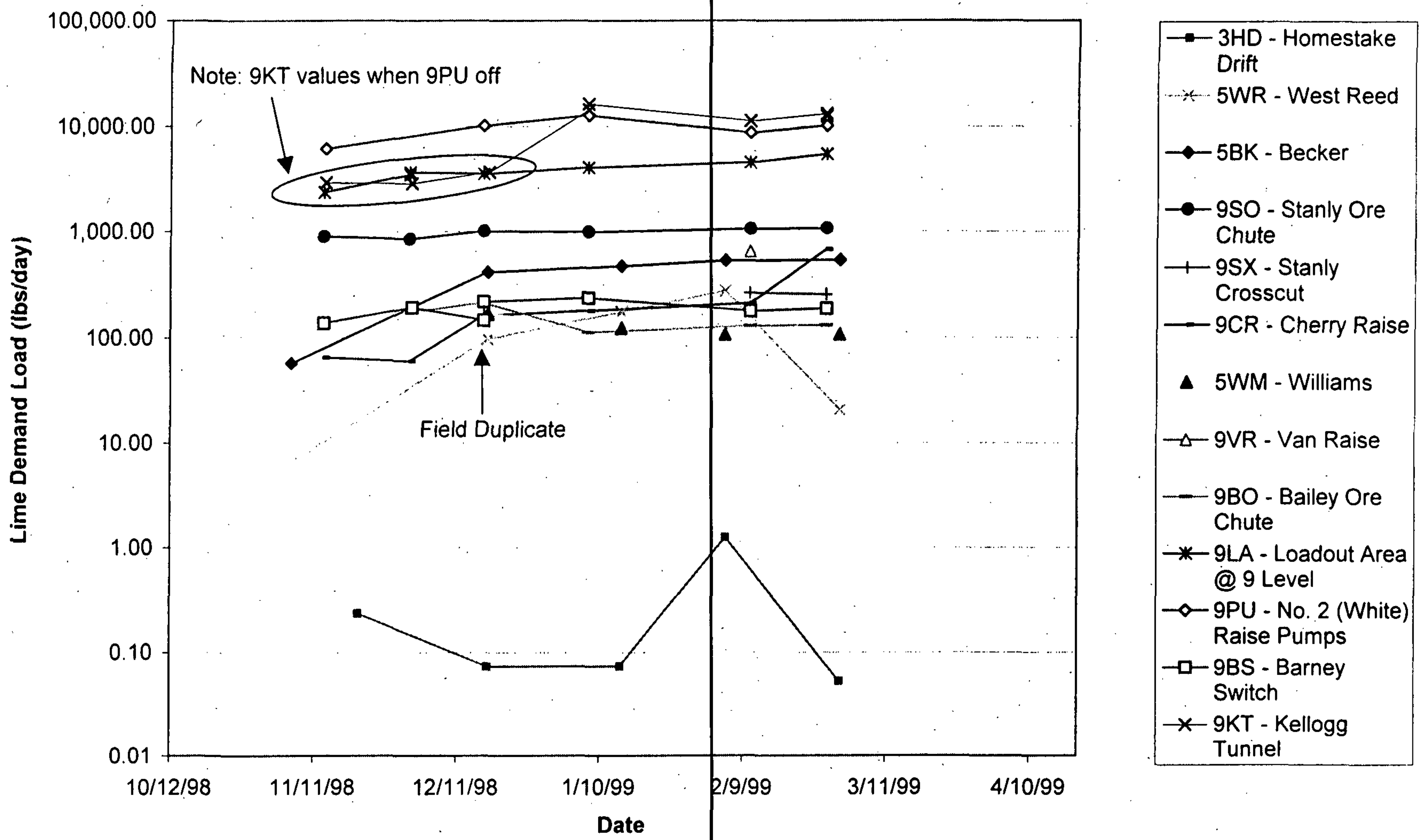

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Figure 6
MASS BALANCES FOR AMD MONITORING NETWORK - 2/5 and 2/10/99 SAMPLING EVENT (PUMPS ON)
BUNKER HILL MINE WATER MANAGEMENT

5WR	Date	Data	%9LA	%9KT
Q	Present	1.9	0.6	0.2
Q	Past	-	-	-
Zn	Present	1,920.0	-	-
Zn	Past	-	-	-
Zn L	Present	44.2	4.4	3.5
LD	Present	100.0	-	-
LDL	Present	275.8	6.2	2.5

5BK	Date	Data	%9LA	%9KT
Q	Present	15.3	4.4	1.2
Q	Past	-	-	-
Zn	Present	465.0	-	-
Zn	Past	-	-	-
Zn L	Present	85.8	8.5	6.7
LD	Present	24.0	-	-
LDL	Present	530.1	11.8	4.7

9VR	Date	Data	%9LA	%9KT	$\%9VR_{Calc}$
Q	Present	135.0	39.1	11.0	93.1
Q	Past	-	-	-	-
Zn	Present	69.7	-	-	-
Zn	Past	-	-	-	-
Zn L	Present	113.2	3.2	2.6	95.2
LD	Present	3.3	-	-	-
LDL	Present	649.3	14.5	5.8	98.0

5WM	Date	Data	%9LA	%9KT
Q	Present	110.4	32.0	9.0
Q	Past	-	-	-
Zn	Present	16.5	-	-
Zn	Past	-	-	-
Zn L	Present	21.9	2.2	1.7
LD	Present	0.7	-	-
LDL	Present	106.5	2.4	0.9

Mass Balance Loop 1:
5BK + 5WM = 9VR

Mass Balance Loop 2:
9VR + 9CR + 9BO + 9SO + 9SX = 9LA

Q - Flow Rate (gpm)
Zn - Zinc Concentration (mg/L)
Zn L - Zinc Loading (lbs/day)
LD - Lime Demand (lbs/1,000 gal)
LDL - Lime Demand Loading (lbs/day)

$\%9VR_{Calc} = (Q_{5BK} + Q_{5WM})/Q_{9VR}*100$
$\%9LA_{Calc} = (Q_{9VR} + Q_{9CR} + Q_{9BO} + Q_{9SO} + Q_{9SX})/Q_{9LA}*100$
$\%9KT_{Calc} = (Q_{9LA} + Q_{9PU} + Q_{9BS})/Q_{9KT}*100$

Note: 5WR tributary to 5BK, thus not included in balance
Flow @ 9VR is the average of 3 visual estimates

9CR	Date	Data	%9LA	%9KT
Q	Present	3.1	0.9	0.3
Q	Past	-	-	-
Zn	Present	898.0	-	-
Zn	Past	-	-	-
Zn L	Present	33.4	3.3	2.6
LD	Present	46.7	-	-
LDL	Present	208.1	4.6	1.9

9LA	Date	Data	%9KT	$\%9LA_{Calc}$
Q	Present	345.4	28.1	79.4
Q	Past	-	-	-
Zn	Present	244.0	-	-
Zn	Past	-	-	-
Zn L	Present	1,013.9	79.5	56.0
LD	Present	9.0	-	-
LDL	Present	4,481.1	39.9	51.3

9BO	Date	Data	%9LA	%9KT
Q	Present	132.7	38.4	10.8
Q	Past	-	-	-
Zn	Present	0.6	-	-
Zn	Past	-	-	-
Zn L	Present	0.9	0.1	0.1
LD	Present	0.7	-	-
LDL	Present	128.0	2.9	1.1

Mass Balance Loop 3:
9LA + 9PU + 9BS = 9KT

9KT	Date	Data	$\%9KT_{Calc}$
Q	Present	1,229.8	106.4
Q	Past	-	-
Zn	Present	86.2	-
Zn	Past	-	-
Zn L	Present	1,275.5	106.0
LD	Present	6.3	-
LDL	Present	11,227.5	118.3

9PU	Date	Data	%9KT
Q	Present	780.0	63.4
Q	Past	-	-
Zn	Present	34.9	-
Zn	Past	-	-
Zn L	Present	327.5	25.7
LD	Present	7.7	-
LDL	Present	8,626.2	76.8

9SO	Date	Data	%9LA	%9KT
Q	Present	1.5	0.4	0.1
Q	Past	-	-	-
Zn	Present	16,600.0	-	-
Zn	Past	-	-	-
Zn L	Present	294.7	29.1	23.1
LD	Present	494.0	-	-
LDL	Present	1,049.5	23.4	9.3

9BS	Date	Data	%9KT
Q	Present	182.9	14.9
Q	Past	-	-
Zn	Present	4.6	-
Zn	Past	-	-
Zn L	Present	10.1	0.8
LD	Present	0.7	-
LDL	Present	176.5	1.6

11VD	Date	Data	%9PU	%9KT
Q	Present	-	-	-
Q	Past	-	-	-
Zn	Present	-	-	-
Zn	Past	-	-	-
Zn L	Present	-	-	-
LD	Present	-	-	-
LDL	Present	-	-	-

9SX	Date	Data	%9LA	%9KT
Q	Present	2.1	0.6	0.2
Q	Past	-	-	-
Zn	Present	4,990.0	-	-
Zn	Past	-	-	-
Zn L	Present	125.6	12.4	9.8
LD	Present	87.1	-	-
LDL	Present	262.4	5.9	2.3

Figure 7
MASS BALANCES FOR AMD MONITORING NETWORK - 2/26 and 3/1/99 SAMPLING EVENT (PUMPS ON)
BUNKER HILL MINE WATER MANAGEMENT

5WR	Date	Data	%9LA	%9KT
Q	Present	0.4	0.1	0.03
Q	Past	-	-	-
Zn	Present	759.0	-	-
Zn	Past	-	-	-
Zn L	Present	3.9	0.3	0.3
LD	Present	33.0	-	-
LDL	Present	20.5	0.4	0.2

5BK	Date	Data	%9LA	%9KT
Q	Present	33.9	9.1	2.5
Q	Past	-	-	-
Zn	Present	234.0	-	-
Zn	Past	-	-	-
Zn L	Present	95.4	8.0	6.3
LD	Present	11.0	-	-
LDL	Present	536.7	10.0	4.1

9VR	Date	Data	%9LA	%9KT	%9VR_{Calc}
Q	Present	138.6	37.2	10.2	104.1
Q	Past	-	-	-	-
Zn	Present	81.1	-	-	-
Zn	Past	-	-	-	-
Zn L	Present	135.2	3.1	2.4	84.5
LD	Present	3.3	-	-	-
LDL	Present	666.5	12.4	5.1	96.5

5WM	Date	Data	%9LA	%9KT
Q	Present	110.4	29.6	8.1
Q	Past	-	-	-
Zn	Present	14.2	-	-
Zn	Past	-	-	-
Zn L	Present	18.9	1.6	1.3
LD	Present	0.7	-	-
LDL	Present	106.5	2.0	0.8

Q - Flow Rate (gpm)
Zn - Zinc Concentration (mg/L)
Zn L - Zinc Loading (lbs/day)
LD - Lime Demand (lbs/1,000 gal)
LDL - Lime Demand Loading (lbs/day)

$\%9VR_{Calc} = (Q_{5BK} + Q_{5WM})/Q_{9VR}*100$
$\%9LA_{Calc} = (Q_{9VR} + Q_{9CR} + Q_{9BO} + Q_{9SO} + Q_{9SX})/Q_{9LA}*100$
$\%9KT_{Calc} = (Q_{9LA} + Q_{9PU} + Q_{9BS})/Q_{9KT}*100$

Note: 5WR tributary to 5BK, thus not included in balance
Flow @ 9VR is the average of 3 visual estimates

Mass Balance Loop 1:
5BK + 5WM = 9VR

Mass Balance Loop 2:
9VR + 9CR + 9BO + 9SO + 9SX = 9LA

Mass Balance Loop 3:
9LA + 9PU + 9BS = 9KT

9CR	Date	Data	%9LA	%9KT
Q	Present	6.4	1.7	0.5
Q	Past	-	-	-
Zn	Present	2,340.0	-	-
Zn	Past	-	-	-
Zn L	Present	179.6	15.1	11.9
LD	Present	73.4	-	-
LDL	Present	674.3	12.6	5.1

9LA	Date	Data	%9KT	%9LA_{Calc}
Q	Present	372.3	27.3	77.0
Q	Past	-	-	-
Zn	Present	265.0	-	-
Zn	Past	-	-	-
Zn L	Present	1,187.1	NA	NA
LD	Present	10.0	-	-
LDL	Present	5,361.4	40.9	52.0

9BO	Date	Data	%9LA	%9KT
Q	Present	134.5	36.1	9.9
Q	Past	-	-	-
Zn	Present	3.4	-	-
Zn	Past	-	-	-
Zn L	Present	5.6	0.5	0.4
LD	Present	0.7	-	-
LDL	Present	129.7	2.4	1.0

9KT	Date	Data	%9KT_{Calc}
Q	Present	1,364.2	91.3
Q	Past	-	-
Zn	Present	91.6	-
Zn	Past	-	-
Zn L	Present	1,503.5	99.3
LD	Present	6.7	-
LDL	Present	13,122.3	119.1

9PU	Date	Data	%9KT
Q	Present	680.0	49.8
Q	Past	-	-
Zn	Present	36.3	-
Zn	Past	-	-
Zn L	Present	297.0	19.8
LD	Present	10.3	-
LDL	Present	10,085.8	76.9

9SO	Date	Data	%9LA	%9KT
Q	Present	1.6	0.4	0.1
Q	Past	-	-	-
Zn	Present	NA	-	-
Zn	Past	-	-	-
Zn L	Present	NA	NA	NA
LD	Present	471.0	-	-
LDL	Present	1,061.6	19.8	8.1

9BS	Date	Data	%9KT
Q	Present	193.1	14.2
Q	Past	-	-
Zn	Present	4.1	-
Zn	Past	-	-
Zn L	Present	9.6	0.6
LD	Present	0.7	-
LDL	Present	186.3	1.4

11VD	Date	Data	%9PU	%9KT
Q	Present	24.9	3.7	1.8
Q	Past	-	-	-
Zn	Present	-	-	-
Zn	Past	-	-	-
Zn L	Present	-	-	-
LD	Present	0.7	-	-
LDL	Present	24.1	0.2	0.2

9SX	Date	Data	%9LA	%9KT
Q	Present	5.6	1.5	0.4
Q	Past	-	-	-
Zn	Present	1,010.0	-	-
Zn	Past	-	-	-
Zn L	Present	68.3	5.8	4.5
LD	Present	31.4	-	-
LDL	Present	254.1	4.7	1.9

4.0 Recommendations

The following recommendations are presented based on the information in this data summary:

- Flow and analytical data presented in this summary suggest that the spring snowmelt has begun. Sampling events should be conducted every two weeks until base flow conditions are re-established, probably in late summer.
- Mass balances indicate that flow, zinc load, and lime demand load are not fully accounted for at 9LA by tributary locations. The missing flow and loads will be explored during the Flood-Stanly reconnaissance (in-mine) that is scheduled to begin within the next few weeks. Additional point sources that are identified will be spot sampled and recommendations to add the locations to the monitoring network will be based on analytical results and flow measurements from temporary flumes.
- Relative proportions of dissolved metals versus total metals have not significantly changed over the course of the monitoring program. Analysis for dissolved ferrous iron indicates that except for the submerged workings, the majority of iron is oxidized and present as ferric iron. It is recommended that the frequency of dissolved metals analysis and dissolved ferrous iron be reduced to once every six weeks or once every three sampling events. If changes in the proportions of dissolved and total metals are observed in subsequent samples, the frequency of dissolved metals analysis will be returned to that of total metals analysis.

5.0 References

CH2M HILL. 1999. Interim Data Evaluation, Bunker Hill Mine Water 1998/1999 Sampling Porgram.

Appendix C

Bunker Hill Mine Area Topography with Surface Features, 5 Level and 9 Level Underground Workings

Appendix D

Historic Data (1983 through 1988)

3HD: 3 Level - Homestake Drift (Bretherton, 1989)

Note: Includes analytical results from Bretherton's Site #13 and flow measurements from Bretherton's Site #12 to match 1998/1999 sampling program.

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-LOG(PH)
3/12/86		36.62							2.8	585		1.58E-03
5/20/86		15.84							2.7	563		2.00E-03
6/10/86		20.88							2.3	667		5.01E-03
6/25/86		12.36							2.4	496		3.98E-03
7/21/86		17.3							2.4	637		3.98E-03
8/21/86		19.5								639		
9/19/86	0.118	20.2							2.1	649		7.94E-03
10/11/86	0.002	34.3							2.1	796		7.94E-03
11/20/86		45.67							2	914		1.00E-02
12/22/86		37.4							2	687		1.00E-02
1/14/87		36.2								890		
1/29/87		50.5							2.9	901		1.26E-03
2/12/87		50.5							2.8	901		1.58E-03
2/26/87		33.5							2.7	896		2.00E-03
3/12/87		142							2.8	1239		1.58E-03
3/20/87	0.049											
3/26/87	0.523	61.1							2.9	827		1.26E-03
4/9/87	0.523	40.2							2.9	698		1.26E-03
4/23/87	0.729	30.4							2.9	669		1.26E-03
5/5/87	0.354	60.6							3	662		1.00E-03
5/21/87	0.354	26.5							2.9	649		1.26E-03
5/28/87	0.354											
6/4/87	0.354	24.1								563		
6/17/87	0.118	24.6							2.8	595		1.58E-03
6/24/87												
6/25/87	0.282											
7/14/87	0.219											
7/19/87	0.118											
7/23/87		33.5								660		
8/13/87	0.080	36								704		
9/16/87	0.118	37.67							2.9	656		1.26E-03
10/21/87	0.027	43.99							2.8	820		1.58E-03
11/26/87												
3/31/88												
4/7/88										2319		
4/14/88										1963		
AVERAGE	0.25	38.13							2.48	830.19		3.30E-03
	AVE. LOAD =	0.12	lbs/day									

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.

5WM: 5 Level - Williams Flume (Riley, 1990 and Bretherton, 1989)

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-LOG pH
1/27/83									4	460	9	1.00E-04
1/28/83	143.8											
2/4/83	148.5								3.3	460	8	5.01E-04
2/17/83	160.5								3.1	450	9	7.94E-04
2/25/83	160.5								3.3	590	9	5.01E-04
3/4/83	169.4								3.2	650	8	6.31E-04
3/11/83	178.5								3			1.00E-03
3/16/83	169.4								3.3	700	12	5.01E-04
3/24/83	188.0	66.21	24.66	101.3				1.564	3.3	660	12	5.01E-04
3/28/83	132.7									240		
4/1/83	192.8								4.9	510	11	1.26E-05
4/8/83	169.1	49.42	18.76	81.12	12.54			0.651	3.5	560	10	3.16E-04
4/15/83	178.5	48.495	18.88	76.34	12.365			0.92	3.3	550	10	5.01E-04
4/22/83	178.5	40.62	16.65	69.41	11.3			0.649	3.2	480	10	6.31E-04
4/29/83	169.1	34.48	14.55	64.45	11.17			0.509	3.5	460	11	3.16E-04
5/6/83	169.1	31.89	13.47	55.39	10.83			0.485	3.2	430	10	6.31E-04
5/13/83	178.5	29.14	13.16	52.91	10.96			0.5475	3.5	400	11	3.16E-04
5/24/83		25.8	11.69	49.75	10.695			0.7175				
6/3/83	156.4	21.95	9.67	41.95	9.26				3.2	380	9	6.31E-04
6/9/83	161.2	24.105	12.67	46.73	10.465				3.6	360	10	2.51E-04
6/15/83	161.2	22.625	16.56	47.34	10.32			0.519	3.1	350	9	7.94E-04
6/24/83	143.8	20.457	8.93	39.72	9.746			0.476	3.1	290	10	7.94E-04
6/29/83	148.5	21.075	9.11	42.61	10.01			0.464	3.8	340	9.1	1.58E-04
7/6/83	143.8	19.855	9.32	41.31	11.225			0.51567				
8/3/83	143.8	16.845	10.95	38.19	10.64			0.409	3.9	310	10	1.26E-04
9/9/83	128.0	14.847	14.83	34.51	12.0725			0.937	4.8		10	1.58E-05
10/6/83	127.8	21.082	68.92	41.02	13.5325	8.708	8.484	5.59	4.6	230	10	2.51E-05
11/10/83	109.0	10.64	4.24	27.78	12.27	6.499	5.365		5	230		1.00E-05
12/8/83	120.1	12.22	5.14	28.72	10.95	6.853	5.288		4.2	230	7	6.31E-05
1/26/84	120.1	14.13	5.38	45.79	12.43	12.61	8.672		4.3	320	8	5.01E-05
2/9/84	110.6	15.375	13.84	44.11	12.535	13	10.279	1.071	4.2	400	6	6.31E-05
2/23/84	110.6	19.52	6.03	46.17	13.58	11.77	10.06		4.6	320	6	2.51E-05
3/8/84	110.6	18.3	6.48	44	11.33	10.43	8.291		4.2			6.31E-05
3/22/84	126.4	33.42	10.55	61.39	12.31	14.37	11.22	0.641	2.9	214	7	1.26E-03
4/5/84	156.4	69.74	21.66	97.62	14.22	18.49	16.76	2.317	3.5	656	7	3.16E-04
4/19/84	173.8	60.9	20.87	84.32	14.76	15.8	14.76	1.809		431	6	
4/26/84	189.6	70.72	24.52	96.29	13.94	17.18	15.34	2.188	3.5	300	7	3.16E-04
5/10/84	173.8	55.75	21.7	82.32	13.99	14.91	13.72	1.448	4.1	307	8	7.94E-05
5/23/84	173.8	51.45	16.28	69.12	12.97	14.5	13.18	0.771	3.7	368	7	2.00E-04
6/8/84	189.6	49.94	16.21	75.38	13.03	14.84	13.3	0.995	2.8	438	9	1.58E-03
6/12/84	189.6	57.24	15.56	83.42	13.53	16.24	14.18	1.18	2.8	420	8	1.58E-03
6/26/84	189.6	50.26	11.03	74.97	13.13	14.26	13.64	1.209	3.5	405	9	3.16E-04
7/19/84	173.8	34.11	9.41	57.43	12.68	10.86	10.45	0.638	3.5	361	9	3.16E-04
7/31/84	173.8	28.41	7.75	50.73	10.63	10.07	9.605	0.506				
8/21/84	173.8	22.24	7.26	43.59	10.09	8.653	7.82	0.494	3.5	302	9	3.16E-04
1/25/85	126.9	12.1	5.3	29.4	10.19	6.6	5.31	0.2	3.4	257	7	3.98E-04
2/21/85	126.9	9.9	4.6	26	10.58	5.91	4.67		3.8			1.58E-04
3/12/85	115.8	8.3	3.9	22.8	9.306	5.71	4	0.3		207	8	
3/28/85	132.7	12.3	3.8	43.4	11.6	14.42	10.74		5.1	240	7	7.94E-06
4/11/85	169.7	20	4.1	57	13.49	19.13	13.64	0.4	3.8	360	7	1.58E-04
5/1/85	169.7	66.1	16.3	88.7	12.67	15.14	14.24	1.936	3.5	550	8	3.16E-04
5/21/85	169.7	44	10.7	70.7	11.03	12.04	10.93	1.11	3.6	420	8	2.51E-04
6/6/85	163.2	34.5	9.6	55.1	10.84	10.47	9.6	0.76	3.7	375	8	2.00E-04
6/25/85	150.7	30.9	8.2	54	10.87	9.24	8.12	0.725	3.5	256	8	3.16E-04
7/30/85	138.6	25.5	5.4	45.6	9.676	8.27	7.04	0.404	3.8	313	9	1.58E-04
8/30/85	132.7	22	5.4	39.1	9.26	7.41	6.57	0.305	3.5	262	9	3.16E-04
10/1/85	126.9	15.6	5.5	30.5	8.694	6.66	5.5	0.217	3.9	155	10	1.26E-04
10/31/85	126.9	14.6	5	28.7	9.622	5.7	4.93		3.8	207	10	1.58E-04
12/18/85	110.4	13.4	4.7	33.4	9.832	5.97	5.07	0.257		246	8	
3/12/86	196.6	100.3							3.2	539		6.31E-04
5/20/86	121.3	44.49							3.3	493		5.01E-04
7/21/86	176.2	28.7							3.6	213		2.51E-04
9/19/86	132.7	14.6							3.3	229		5.01E-04
10/11/86	127.0	12.32							3.6	151		2.51E-04
11/20/86	121.3	10.21							3.2	118		6.31E-04
12/22/86	110.4	10.2							3.4	171		3.98E-04
1/14/87	115.8	11							3.1	211		7.94E-04
1/29/87	115.8	9.39							3.9	184		1.26E-04

METALS NOT COMPLETED

5WM: 5 Level - Williams Flume (Riley, 1990 and Bretherton, 1989)

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-LOG pH
2/12/87	132.7	8.54							3.8	171		1.58E-04
2/26/87	110.4	11.5							3.9	217		1.26E-04
3/12/87	132.7	19							3.7	339		2.00E-04
3/26/87	150.7	37.6							3.2	438		6.31E-04
4/9/87	144.6	48.6							3.5	428		3.16E-04
4/23/87	144.6	44.7							3.3	410		5.01E-04
5/5/87	150.7	42.6							3.5	403		3.16E-04
5/21/87	144.6	38.9							3.2	389		6.31E-04
6/4/87	144.6	33							3.2	353		6.31E-04
6/17/87	144.6	31							3.4	343		3.98E-04
7/23/87	144.6	26.7								343		
8/13/87	127.0	19.7							3.9	275		1.26E-04
9/16/87	115.8	14.02							3.7	215		2.00E-04
10/21/87	99.9	11.13							3.8	168		1.58E-04
12/8/87	30.8								5.2	98		6.31E-06
2/11/88	90.0								5.3	115		5.01E-06
2/17/88	90.0								5.3	124		5.01E-06
3/10/88	94.9								5.2	133		6.31E-06
3/16/88	94.9								4.6	165		2.51E-05
3/31/88	47.4								3.3	257		5.01E-04
4/14/88	115.8								2.9	406		1.26E-03
AVERAGE	142.48	29.73							3.43	339.64		3.68E-04
	Ave. Load =	50.90	lbs/day									

METALS NOT COMPLETE

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.

5WR: 5 Level - West Reed Flume (Riley, 1990 and Bretherton, 1989)

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	
10/6/83		529.2	641.65	1017.1	39.82	78.24	122.45	2.788	2.6	3800	10	2.51E-03
11/10/83		361.2	406.3	637.9	31.74	57.09	77.87	0.843	2.7	3000		2.00E-03
12/8/83		705	1056	1480	44.59	95.72	124.8	6.768	2.4	4500	12	3.98E-03
1/26/84		1229	2374	3246	84.58	224.4	344.8	14.13	2.5	6400	12	3.16E-03
2/9/84		1439	2548.5	2981.5	92.605	206	318.3	17.395	2.3	8100	11	5.01E-03
2/23/84		1205	2133	2911	75.71	161.8	262.9	11.76	2.7	7400	11	2.00E-03
3/8/84		1009	1771	2389	63.94	132.9	230.4	7.094	2.6			2.51E-03
3/22/84		1087	1622	2223	55.16	123	174.6	25.35	2.1	5159	11	7.94E-03
4/5/84		1384	1829	2385	66.24	138.6	225.4	21.72	2.4	5200	13	3.98E-03
4/19/84		1255	1773	2336	60.73	125.2	205.5	22.53		5368	12	
4/26/84		1182	1723	2177	62.35	130.9	194.8	22.81	2.5	5365	13	3.16E-03
5/10/84		1145	1714	1980	61.98	123.1	203.7	14.67	2.8	4869	11	1.58E-03
5/23/84		978.7	1449	1839	57.2	115.9	190.8	9.825	2.7	3028	10	2.00E-03
6/8/84		1047	1413	1837	55.96		184.2	18	2.3	4856	11	5.01E-03
6/12/84		1074	1444	2080	54.93	115.6	186.2	16.41	2.4	4799	12	3.98E-03
6/26/84		1017	1370	2044	59.27	124.9	185.9	12.99	2.4	4705	13	3.98E-03
7/29/84		841.3	1160	1618	57.84	114.3	172.5	5.81	2.6	4152	12	2.51E-03
7/31/84		697.3	1052	1354	50.22	99.04	163.7	4.245	2	3678	13	1.00E-02
8/21/84		603.2	900.1	1279	46.06	92.86	148.3	4.853	2.4	3335	13	3.98E-03
1/25/85	2.2	2527	4672	5670	142	353.1	577.2	11.6	2	9421	10	1.00E-02
2/21/85	5.8	547.5	948.8	1287	39.31	75.54	144	3	2.3			5.01E-03
3/12/85	6.7	530.2	1006	1298	46.53	92.5	164.6	1.1		3486	10	
3/28/85	2.7	727.8	2024	2311	81.18	173	304.6	3.1	2.6	179	8	2.51E-03
4/11/85	29.2	606	283	1655	50.15	113.9	136.6	24.4	2.6	4130	11	2.51E-03
5/1/85	20.5	1491	1891	2423	55.19	113.9	172.8	30.26	2.6	5390	13	2.51E-03
5/21/85	17.5	1071	1467	1971	47.74	99	171.3	15.54	2.6	4819	13	2.51E-03
6/6/85	14.4	886.4	1236	1618	43.87	93.25	163.5	11.39	2.6	4287	13	2.51E-03
6/25/85	14.4	795.7	1138	1421	40.84	93.2	119.7	9.593	2.6	4140	12	2.51E-03
7/30/85	10.2	752.7	1075	1461	50.95	111.7	151	7.462	2.8	3606	14	1.58E-03
8/30/85	8.5	634.4	795.2	1263	42.89	86.12	126.4	5.11	2.6	3133	14	2.51E-03
10/1/85	6.7	549.5	774.5	1158	40.78	81.07	119.4	3.142	2.5	2560	15	3.16E-03
10/31/85	6.7	475.8	731.5	1076	36.98	72.14	104.8	2.477	2.3	3108	15	5.01E-03
12/18/85	5.8	839.2	1235	1716	47.74	102.8	168	4.454		4385	12	
3/12/86		1565							2.4	4127		3.98E-03
5/20/86	16.2	1086							2.6	3194		2.51E-03
7/21/86		687.4							2.5	2760		3.16E-03
8/21/86	8.5	607.9								3506		
9/19/86		499.2							2.6	1966		2.51E-03
10/11/86		363							2.4	1480		3.98E-03
11/20/86		297							2.3	1913		5.01E-03
12/22/86		803							2.3	3361		5.01E-03
1/14/87	4.5	821							2.2	3081		6.31E-03
1/29/87	4.8	830							2.7	3674		2.00E-03
2/12/87	5.6	621							2.5	3501		3.16E-03
2/26/87	4.9	551							2.6	3895		2.51E-03
3/12/87	14.4	907							2.4	5542		3.98E-03
3/20/87	14.4								2.4	6070		3.98E-03
3/26/87	5.4	1290							2.2	6136		6.31E-03
4/2/87	11.2								2.4	5938		3.98E-03
4/9/87	11.2	1150							2.6	5209		2.51E-03
4/23/87	10.8	1160							2.5	5344		3.16E-03
5/5/87	10.3	1200							2.6	4703		2.51E-03
5/21/87	9.9	946							2.5	4882		3.16E-03
6/4/87	7.2	808							2.5	4291		3.16E-03
6/17/87	7.6	840							2.5	4103		3.16E-03
7/23/87	5.8	687								3751		
8/13/87	4.9	579							2.9	3656		1.26E-03
9/16/87	4.0	665.4							2.6	3798		2.51E-03
10/21/87	3.8	440.3							2.6	2608		2.51E-03
12/8/87	2.5								2.5	3430		3.16E-03
2/11/88									2.6	3157		2.51E-03
2/17/88									2.6	3163		2.51E-03
3/10/88	6.7								2.7	2719		2.00E-03
3/16/88	5.6								2.5	3970		3.16E-03
3/31/88	9.2								2.4	6056		3.98E-03
4/14/88	12.1								2.4	7402		3.98E-03
AVERAGE	9.05	888.20							2.45	4261.66		3.53E-03
	AVE. LOAD =	96.59	lbs/day									

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.

5BK: 5 Level - Becker Flume (Riley, 1990 and Bretherton, 1989)

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-Log pH
1/27/83									2.5	4000	9	3.16E-03
2/4/83	55.1								3	1960	6	1.00E-03
2/17/83	64.8								2.8	1610	9	1.58E-03
2/25/83	86.9								2.7	1610	10	2.00E-03
3/4/83									2.9	1290	10	1.26E-03
3/11/83	113.3								2.9	1600	31	1.26E-03
3/16/83	113.3								2.8	1525	10	1.58E-03
3/24/83	86.9	192	210	403				5.517	2.8	1850	9	1.58E-03
4/1/83	86.9								2.8	1780	12	1.58E-03
4/8/83	86.9	182.8	225	373.7	19.54			2.594	2.9	1750	11	1.26E-03
4/15/83	69.5	193.25	213.05	384	21.995			2.896	2.8	1840	12	1.58E-03
4/22/83	80.6	143.9	162.4	301.2	18.28			2.2285	2.8	1500	12	1.58E-03
4/29/83	80.6	149	174.1	312.95	16.875			1.7485	3	1475	10	1.00E-03
5/6/83	93.2	92.44	92.68	183.9	11.74			1.272	2.8	1230	10	1.58E-03
5/13/83	99.5	97.15	106.8	196.25	13.265			1.0555	2.8	1100	10	1.58E-03
5/24/83	105.9	78.52	91.84	169.1	12.11			0.45	2.8	960	10	1.58E-03
6/3/83	99.5	87.12	70.65	178.95	12.45			0.64	2.6	1030	10	2.51E-03
6/9/83	80.6	96.08	64.62	181.9	12.915			0.7925	3.1	1080	10	7.94E-04
6/15/83	80.6	83.87	59.74	174.85	12.63			0.924	3.1	1050	11	7.94E-04
6/24/83	75.8	64.105	59.18	127.05	10.995			0.69	2.5	880	11	3.16E-03
6/29/83	75.8	80.13	67.9	161.03	12.0133			0.6297	3.3			5.01E-04
7/6/83	69.5	76.035	73.65	163.75	11.685			0.699	3.2	1268	14	6.31E-04
8/3/83	60.0	90.605	81.37	194.45	15.195			1.177	3	1410	12	1.00E-03
9/9/83	49.0	89.975	98.45	201.55	15.145			0.739	3.1	1602	10	7.94E-04
10/6/83	46.5	81.325	53.55	149.55	13.375	21.515	17.645	0.867	2.7	1305	10	2.00E-03
11/10/83	37.9	53.1	31.7	101.6	13.46	16.83	11.59	0.173	2.8			1.58E-03
12/8/83	45.8	50.96	45.5	116.6	12.95	18.61	10.81	0.836	3.1	1165	6	7.94E-04
1/26/84	25.3	250.4	466.2	686.9	32.5	77.61	57.84	3.515	2.8	2600	8	1.58E-03
2/9/84	11.2	520.3	969.3	1249.5	47.055	108.355	80.85	7.4085	2.6	3500	12	2.51E-03
2/23/84	13.3	509.9	933.1	1250	41.27	96.04	107.6	5.588	2.8	4000	9	1.58E-03
3/8/84	13.3	458.5	786.3	1043	39.54	93.22	100.1	3.541	2.6			2.51E-03
3/22/84	47.4	428.9	643.9	852.5	29.3	70.22	66.09	10.85	2.3	2113	10	5.01E-03
4/5/84	33.2	822.3	1185	1400	48.33	101.3	136.4	14.5	2.8	4537	8	1.58E-03
4/19/84	36.3				30.52	69.08		8.792		2665	10	
4/26/84	41.1	533	752.5	973.3	34.14	78.19	79.24	9.901	2.6	2842	7	2.51E-03
5/10/84	36.3	433	640.4	766	30.32	66.77	80.72	5.752	2.9	2282	8	1.26E-03
5/23/84	39.5	365.4	509.9	681.7	26.69	57.77	71.07	3.984	2.8	1932	8	1.58E-03
6/8/84	39.5	423.3	569.4	763.7	30.79	64.54	78.13	6.815	2.3	2306	9	5.01E-03
6/12/84	44.2	435.3	579.6	844.6	28.93	64.48	75.15	7.305	2.5	2389	9	3.16E-03
6/26/84	36.3	387.2	494.4	787.7	30.03	62.81	71.28	5.299	2.5	2347	9	3.16E-03
7/19/84	30.0	283.2	396.1	566.2	25.27	52.5	61.53	2.406	2.7	2554	10	2.00E-03
7/31/84	22.1	292.4	364.7	589.9	25.23	55.84	67.58	2.004	2.1	2608	10	7.94E-03
8/21/84	20.5	293.1		629.2	28.25	62.37	71.55	2.444	2.6	2572	10	2.51E-03
1/25/85	71.5	220.1	401.7	508.9	21.8	48.01	53.39	1.2	2.4	2000	7	3.98E-03
2/21/85		169.4	284.5	382.6	18.38	38.5	45.12	0.5				
3/12/85	13.2	209.3	377	535.5	24.27	49.44	59.9	0.6		1834	8	
3/28/85	22.5	216	564.9	695.4	34.19	76.9	93.55	1	2.9	2184	8	1.26E-03
4/11/85	71.5	223.1	444.4	592	28.04	71.67	52.78	10	2.8	2087	9	1.58E-03
5/1/85	40.4	646.8	811	1028	30.16	65.33	77.69	13.66	2.9	3042	10	1.26E-03
5/21/85	33.9	380.4	419	712.1	22.31	51.21	56.08	6.377	2.9	2167	10	1.26E-03
6/6/85	40.4	306.1	416.4	605.4	21.08	47.54	53.09	4.527	2.9	2005	10	1.26E-03
6/25/85	33.9	303.6	338.8	556.5	20.75	48.23	47.75	3.87	2.8	2046	10	1.58E-03
7/30/85	40.4	294.5	364.7	572.1	23.37	52.98	54.96	2.207	3	1940	11	1.00E-03
8/30/85		224.1	208.4	462.8	21.56	49.15	54	2.245	2.8	1649	11	1.58E-03
10/1/85	6.3	3		16.5	5.143	9.88	1.1		4.9	135	11	1.26E-05
10/31/85	30.8	51	57.7	133.5	12.5	24.47	13.52	0.482	2.8	802	12	1.58E-03
12/18/85	13.2	3.7	0.2	52	9.584	29.78	3.25			328	10	
3/12/86		682.9							2.6	2261		2.51E-03
5/20/86	37.1	362.7							2.8	1485		1.58E-03
7/21/86	22.5	281.7							2.7	1188		2.00E-03
8/21/86	20.0	194.7								1715		
9/19/86	15.3	151.9							2.6	417		2.51E-03
10/11/86	17.6	119							2.4	659		3.98E-03
11/20/86	20.0	84.85							2.3	625		5.01E-03
12/22/86	17.6	322							2.3	1571		5.01E-03
1/14/87	15.3	212							2.3	1428		5.01E-03
1/29/87		201							2.9	1714		1.26E-03
2/12/87	17.6	163							2.8	1571		1.58E-03

METALS NOT COMPLETE

5BK: 5 Level - Becker Flume (Riley, 1990 and Bretherton, 1989)

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-Log pH
2/26/87	15.3	440							2.7	2999		2.00E-03
3/12/87	43.8	337							2.7	2772		2.00E-03
3/20/87	40.4								2.6	3050		2.51E-03
4/9/87	40.4	424							2.8	2618		1.58E-03
4/23/87	40.4	286							2.8	2170		1.58E-03
5/5/87	40.4	264							2.9	1941		1.26E-03
5/21/87	33.9	300							2.7	2196		2.00E-03
6/4/87	33.9	204							2.7	1784		2.00E-03
6/17/87	30.83	222							2.7	1682		2.00E-03
7/23/87	19.96	193								1626		
8/13/87	13.24	166							3.4	1319		3.98E-04
9/16/87	15.34	112.7							3	1009		1.00E-03
10/21/87	19.96	96.87							2.8	901		1.58E-03
12/8/87	14.27								2.9	702		1.26E-03
2/11/88	15.34								2.8	714		1.58E-03
2/17/88	17.58								2.9	980		1.26E-03
3/10/88	22.47								2.9	910		1.26E-03
3/16/88	17.58								2.6	1386		2.51E-03
3/31/88	25.13								2.5	2801		3.16E-03
4/8/88	43.82									3022		
4/14/88	40.38								2.5	1682		3.16E-03
AVERAGE	43.61	246.35							2.70	1814.55		2.01E-03
	Ave. Load=	129.08	lbs/day									

Metals not complete

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.

9BO: 9 Level - Bailey Ore Chute (Riley, 1990)

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-Log pH
2/25/83									5.1	76	15	7.94E-06
3/4/83									3.9	68	16	1.26E-04
3/11/83									4.1	62	16	7.94E-05
4/8/83									4.2	85	16	6.31E-05
4/15/83									3.4	85	18	3.98E-04
4/22/83		0.158	4.094	9.663	2.753			0.44	3.6	92	18	2.51E-04
5/13/83									3.6	96	15	2.51E-04
5/24/83										115	14	
6/3/83		0.225	6.054	9.16	2.852				3.3	127	15	5.01E-04
6/9/83		0.231	6.855	11.27	2.95			0.454	3.9	112	14	1.26E-04
6/24/83		0.3025	7.105	10.665	3.3045			0.576	3.7	115	15	2.00E-04
6/29/83		0.295	7.684	11.315	3.02			0.6015	3.9	124	14	1.26E-04
7/6/83		0.292	7.5425	10.755	2.8975			0.5195	3.9	127	15	1.26E-04
8/3/83		0.35	8.1325	12.055	3.3155			0.614	3.9	126	15	1.26E-04
9/9/83		1.062	8.539	15.545	3.8175			0.436	3.7	118	14	2.00E-04
11/10/83		0.326	7.787	8.111	2.996	1.031	0.963	0.231	3.9	115	15	1.26E-04
12/8/83	87.135	0.258	5.334	7.152	3.02	0.969	0.782		3.8	96	14	1.58E-04
1/26/84	85.55	0.199	4.384	5.731	2.991	0.699	0.61		4.1	100	13	7.94E-05
2/9/84	95.056	0.189	4.794	7.4955	3.0025	0.725	0.695	0.204	4.2	92	14	6.31E-05
2/23/84	90.303	0.159	4.458	7.054	3.036	0.754	0.613	0.393	3.7	83	14	2.00E-04
3/8/84	91.887	0.214	4.583	8.956	3.203	0.687	0.623		3.5	83	14	3.16E-04
3/22/84	98.224	0.169	4.447	8.199	2.749	0.68	0.595		3.4	57.293	15	3.98E-04
4/5/84	91.887	0.231	5.202	8.548	3.078	0.813	0.704	0.469	3.5	82.892	15	3.16E-04
4/19/84	99.809	0.196	5.131	8.317	2.853	0.776	0.717	0.385		37.789	15	
4/26/84	99.809	0.218	5.128	7.983	2.774	0.761	0.707		3.8	45.695	17	1.58E-04
5/10/84	121.988	0.176	5.205	5.59	2.84	0.682	0.708	0.313	3.6	78.016	15	2.51E-04
5/23/84	128.325	0.123	7.61	12.14	3.003	0.844	0.895	0.998	3.4	200.776	16	3.98E-04
6/8/84	133.078	0.323	7.733	11.33	2.881	7.738	0.883	1.06				
6/12/84	126.741	0.357	7.815	15.38	3.099	0.965	0.966	1.024	3.3	131.46	16	5.01E-04
6/26/84	134.662	0.338	11.36	12.98	3.069	1.007	1.031	1.246	5	107.272	15	1.00E-05
7/19/84	136.247	0.582	9.503	14.87	3.207	1.169	1.147	1.245	3.5	119.461	15	3.16E-04
7/31/84	134.662	0.379	8.767	14.09	3.136	1.034	1.055	1.055	3.4	128.068	14	3.98E-04
9/19/84		0.381	9.269	13.6	3.287	1.024	1.077	0.633	3.7	121.851	14	2.00E-04
1/25/85		0.27	7.214	10.7	3.197	0.95	0.91	0.53	3.6	94.496	14	2.51E-04
2/21/85	113.7	0.223	6.537	9.5	3.158	0.9	0.85	0.405	4	92.865	10	1.00E-04
3/12/85	120.17	0.23	6.717	10.1	3.128	0.37	0.8	0.369	3.7	82.791	12	2.00E-04
3/28/85	116.44	0.211	6.572	9.6	2.864	0.77	0.82	0.426	4.1	95.118	13	7.94E-05
4/11/85	108.6	0.334	6.668	10.4	3.179	0.91	0.8	0.459	4.2	93.85	13	6.31E-05
5/1/85	123.26	0.25	7.676	10.6	2.918	0.9	0.93	0.47	3.9	110.66	14	1.26E-04
5/21/85	131.33	0.264	7.1	12.3	3.384	0.86	0.92	0.679	3.9	113.534	16	1.26E-04
6/6/85	143.5	0.278	7.221	12	3.202	0.92	0.94	0.789	3.6	127.994	15	2.51E-04
6/25/85	150.05	0.33	7.149	10.6	2.899	0.86	0.96	0.856	3.6	130.654	12	2.51E-04
7/30/85	156.43	0.597	8.131	14.2	3.082	1.03	1.09	0.991	3.6	134.741	17	2.51E-04
8/30/85	143.89	0.294	9.356	14.6	3.22	0.91	1.09	0.629		119.509	16	
10/1/85	108.4	0.349	8.65	9.8	3.77	0.96	1.1	0.566	3.8	127.994	15	1.58E-04
10/31/85		0.34	8.412	8.8	3.479	1	1	0.329	3.5	115.804	15	3.16E-04
12/18/85	130.82	0.278	6.786	10.6	3.036	0.96	0.9	0.396		188.637	17	
AVERAGE	117.93	0.30							3.69	105.14		2.06E-04
	Ave. Load	0.42	lbs/day									

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.

9CR: 9 Level - Cherry Raise (Riley, 1990)

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-Log pH
2/25/83									2.3	5900	22	5.01E-03
3/4/83									2.1	7400	23	7.94E-03
3/11/83									2.2	6800	22	6.31E-03
3/24/83		2139	1880	3489				52.2	2.4	7400	26	3.98E-03
4/1/83									1.9	6600	22	1.26E-02
4/8/83		1452	1380	2393	65.64				2.4	6400	22	3.98E-03
4/15/83		1536	1613	2244	73.37				2.1	6400	24	7.94E-03
4/22/83		1524	1666	2394	64.79				2.4	6500	24	3.98E-03
5/13/83		1355	1429	2179	62.45				2.2	5700	22	6.31E-03
5/24/83		1196.5	1265	1883	52.215					5400	21	
6/3/83		1980	2227	3387	84.62				1.9	8200	22	1.26E-02
6/9/83		1622.5	1804.5	2738.5	70.425				2.4	6900	22	3.98E-03
6/24/83		848	930.35	1419	44.285				2.5	4600	22	3.16E-03
6/29/83		888	956.8	1719	58.01				2.6	5078.8	20	2.51E-03
7/6/83		865.9	940.8	1538.33	44.787				2.6			2.51E-03
8/3/83		649.75	692.55	1170.5	39.97				2.7	4244.8	22	2.00E-03
9/9/83		310.97	282.82	579.52	21.79			3.504	2.7	2971.4	22	2.00E-03
10/6/83		277.1	222.1	495.5	19.54	48.48	61.415	3.276	3	2760.2	20	1.00E-03
11/10/83		208.6	174.5	375.6	15.35	36.8	50.55	2.859	2.6	2539.4	20	2.51E-03
12/8/83	13.746	291.1	317.6	302.7	16.46	36.87	49.62	2.265	2.2	2527.1	18	6.31E-03
1/26/84	17.38	456.6	763.1	1023	23.51	48.5	70.53	6.069	2.4	3300	18	3.98E-03
2/9/84	20.54	684.4	1140	1396	35.69	78.485	120.4	11.64	2.4	4200	17	3.98E-03
2/23/84	18.96	808.2	1173	1607	35.65	90.51	107.6	15.45	2.3	4500	18	5.01E-03
3/8/84	17.38	928.3	1229	1685	34.95	98.74	156.3	16.39	2.5	4700	18	3.16E-03
3/22/84	22.12	1108	1628	1997	41.48	110.6	192.9	17.87	1.9	4162.4	20	1.26E-02
4/5/84	25.28	2096	2642	3580	75	247	357.9	39.99	2.5	3201.8	20	3.16E-03
4/19/84	18.96	2878	3425	4761	87.06	310.7	489.9	53.31		9009.3	19	
4/26/84	30.02	3017	3612	5394	102.1	341.3	497.8	87.03	2.4	11036.4	19	3.98E-03
5/10/84	23.7	2934	3277	4312	95.73	285	428.7	35.71	2.6	5007.4	16	2.51E-03
5/23/84	23.7	3606	4344	6148	110.8	365	544.5	114.7	2.3	7793.5	21	5.01E-03
6/8/84	23.7	3753	4427	6248	104.8	367	548.3	113.8	2.5		19	3.16E-03
6/12/84	17.38	3800	4685	6697	98.7	372.5	525.9	111.2	2	11142.3	18	1.00E-02
6/26/84	11.534	2988	3530	5424	97.55	316.9	455	57.58	2.3	9419.2	18	5.01E-03
7/19/84	7.742	1879	1867	2998	77.5	200.9	283	17.85	2.4	6975.3	19	3.98E-03
7/31/84	7.742	1751	1694	2619	72.42	191	272.1	15.57	2.3	6333.5	18	5.01E-03
9/19/84		1057	1130	1724	52.78	131.7	188.9	9.392	2.8	5355.9	16	1.58E-03
1/25/85	5.9027	1334	1612	2292	58.11	135.3	192.6	10.6	2.1	5349.3	19	7.94E-03
2/21/85	6.7245	1437	1796	2474	60.73	141.5	218.3	10.8	1.9	5666	12	1.26E-02
3/12/85	3.7772	1377	1772	2423	57.05	134.9	211.5	10.8	2.3	5247	14	5.01E-03
3/28/85	6.7245	2499	4152	4893	105.5	254.5	396.8	16.8	2.3	8703.6	14	5.01E-03
4/11/85	7.6038	2832	5301	6148	114.8	283	474.9	19.7	2.3	10158.3	16	5.01E-03
5/1/85	16.764	4995	4987	8200	121.6	444	645.6	115.1	2.1	14294.2	17	7.94E-03
5/21/85	33.748	4014	4937	7092	96.06	419.7	605.7	101	2.2	12750.4	18	6.31E-03
6/6/85	24.469			7712	131.5	452.3	588.9	142.2	2.2	12419.6	17	6.31E-03
6/25/85	12.88	4041	4463	7224	91.18	453.6	658.3	104.3	2.1	11336.6	15	7.94E-03
7/30/85	11.706	3118	3509	5294	109	408.5	532.3	72.31	2.2	8875.9	21	6.31E-03
8/30/85	8.541	1119	1182	3729	85.32	268.7	329	42.49		8551.2	21	
10/1/85	6.724	1519	1470	2490	62.43	202.8	306	21.4	2.3	6092.6	17	5.01E-03
10/31/85	7.604	1058	993.7	1974	54.65	163.1	224.7	15.59	2.1	4932.7	17	7.94E-03
12/18/85	8.541	2114	2442	3741	83.24	310.6	425.9	43.7		8959.7	18	
AVERAGE	15.39	1829.91							2.26	6745.75		5.48E-03
	Ave. Load=	338.32	lbs/day									

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.

9SX: 9 Level - Stanly Crosscut (Riley, 1990)

Note: 1998/1999 sampling program only includes flow measurement at this location.

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-Log pH
6/8/84		1776	1861	3038	184.5	230.9	240.4	52.83	2.8	8553.1	17	1.58E-03
7/31/84		1482	1371	2360	137.7	202.9	186	40.06	2.4	6948.3	15	3.98E-03
9/19/84		1501	1416	2318	133.2	206.6	186.3	42.59	2.7	6227.1	13	2.00E-03
1/25/85	9.2908	1686	1506	2656	134.8	218.9	203	42.1	2.3	6338.7	12	5.01E-03
2/21/85	0.4717	1688	1612	2796	142.2	237.3	208.5	43	2.4	6196.4	12	3.98E-03
3/12/85	1.4145	1708	1539	2708	155	221.6	212.2	42	2.3	6848.5	13	5.01E-03
3/28/85	2.09	1748	1574	2434	145.5	226.5	209.3	44.9	2.5	10146	13	3.16E-03
4/11/85	0.4717	1714	597	2696	140.5	231.9	217.7	42.2	2.5	6975	13	3.16E-03
5/1/85	17.2453	1404	1372	2549	132.3	188.6	181.2	38.56	2.3	6216.9	15	5.01E-03
5/21/85	24.9536	1469	1570	2755	148.7	169.3	189.4	41.45	2.4	6704.5	15	3.98E-03
6/6/85	27.863	1672	1650	2805	145.4	184.9	214.6	45.32	2.5	6704.5	15	3.16E-03
6/25/85	22.2152	1613	1376	2520	131.7	204.8	189.6	38.82	2.2	6338.8	15	6.31E-03
7/30/85	22.2152			2729	157	226.9	188.1	49.72	2.5	5266.1	15	3.16E-03
8/30/85	19.6462	1540	1409	2421	139.2	199.3	180.3	42.92	2.5	6216.9	15	3.16E-03
10/1/85	9.2908	1588	1397	2454	127.9	192.9	195.2	39.41	2.5	5358.9	14	3.16E-03
10/31/85	2.9159	1809	1513	2694	131.4	199	215.5	42.43	2.2	5278.2	15	6.31E-03
12/18/85	5.0054	1716	1374	2552	133.3	187.4	214.8	40.02		5470.8	14	
AVERAGE	11.79	1632.13							2.41	6575.81		3.88E-03
	Ave. Load=	231.26	lbs/day									

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.

9SO: 9 Level - Stanly Ore Chute (Riley, 1990)

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-Log pH
2/17/83									2		20	1.00E-02
2/25/83	0.948								1.9		18	1.26E-02
3/4/83									1.9		18	1.26E-02
3/11/83	1.106								1.9		18	1.26E-02
3/24/83	1.422	18212	16640	29020				682	2		22	1.00E-02
4/1/83									1.9		18	1.26E-02
4/8/83	1.264	18436	16846	27272	577.4			380.7	2.1			7.94E-03
4/15/83	1.264	18330	17486	27559	611.5			456	1.9			1.26E-02
4/22/83	1.106	17775	16563	27091	564.3			472	2			1.00E-02
5/13/83	1.264	18341.5	16794	27035	561.6			478.9	1.8		14	1.58E-02
5/24/83		18197	16462	26913	585			297.3			18	
6/3/83		16768	14940	24851	534.4			271.4	1.6			2.51E-02
6/9/83		17449	15829	26898	540.9			287.9	2.1			7.94E-03
6/24/83		17406.5	16668	26523.5	537.4			472.1	1.8			1.58E-02
6/29/83		19028.7	17988	29289.7	576.6			464.1	2			1.00E-02
7/6/83		18995	18168	28338	584.65			456.4	2.2			6.31E-03
8/3/83		17983.8	17647.3	28952.5	580.3			489.825	2.2			6.31E-03
9/9/83		18535	18840.5	30150	563.3			463.75	2.2			6.31E-03
10/6/83	0.632	19988.5	18455.5	28938.5	537.65	2275.5	3137	501.5	2			1.00E-02
11/10/83	0.632	19660	17915	28338	574.2	2226	3030	411.6	2.2			6.31E-03
12/8/83	0.632	19833	18601	32561	534	2231	3150	446.8	1.8			1.58E-02
1/26/84	0.474	17727	18357	30177	518.9	2270	3232	394.3	1.9			1.26E-02
2/9/84	0.948	16970	17557.5	27543.5	574.55	2273	2977	403.55	1.9			1.26E-02
2/23/84	0.79	17250	17988	28691	475.9	2200	3191	350.9	2			1.00E-02
3/8/84	0.79	17809	17515	28049	533.7	2334	3209	383.3	2			1.00E-02
3/22/84	0.948	17272	16844	26790	479.8	2270	3004	377.2	1.8	16412.5	14	1.58E-02
4/5/84	2.212	17711	17020	27199	480	2374	3161	366.8	1.8	15853	13	1.58E-02
4/19/84	1.106	18400	17882	28042	494.5	2367	3292	380.5		32700.7	14	
4/26/84	1.106	16073	15377	25423	436.1	1827	2690	378.6	2.1	20722.9	15	7.94E-03
5/10/84	1.422	18164	17852	27397	482.2	2251	2941	398.8	2.3	32452.1	14	5.01E-03
5/23/84	2.054	17032	17030	26124	441.1	1750	2506	381.5				
6/8/84	9.006	8907	7573	12386	261.8	748.4	999	249.6	2.2	19757.4	18	6.31E-03
6/12/84	7.426	9039	7877	13762	289.9	809.7	1017	279.3	2.1	28280.7	15	7.94E-03
6/26/84	3.318	13288	11500	19499	368.5	1334	1635	355.4	2.2	25964.6	15	6.31E-03
7/19/84	2.054	18281	15029	25430	450	1853	2243	463.3	2.2	29621.6	15	6.31E-03
7/31/84	1.738	19595	15357	26748	426.2	1924	2439	434.2	2.1	28473.3	14	7.94E-03
9/19/84		20975	17210	28364	447.8	1977	2617	459.4	2.5	28915.9	13	3.16E-03
1/25/85	1.324	17821	14605	28571	472.4	2367	2858	365.6	2.1	30184.2	13	7.94E-03
2/21/85	0.948	19284	16165	28734	466.1	2263	2912	409.3	2.2	30787.8	12	6.31E-03
3/12/85	0.966	19684	16712	29857	418.3	2215	2850	358.7	2	29965.3	14	1.00E-02
3/28/85	1.233	17969	16509	27291	463.2	2114	2751	370.9	1.9	31579.2	13	1.26E-02
4/11/85	1.109	17494	662	27305	470	2066	2626	380.4	2	29965.3	14	1.00E-02
5/1/85	2.982	12348	11012	20124	339.9	1469	1836	286.4	2	24501.8	15	1.00E-02
5/21/85	10.968	8042	6541	11287	168.9	742	870.4	232.5	2.1	18723.6	18	7.94E-03
6/6/85	5.39	10530	8728	15020	338.2	1001	1165	302.5	2.2	21324.2	17	6.31E-03
6/25/85	2.21	14663	11067	21791	356.3	1247	1623	362.5	2	25598.9	15	1.00E-02
7/30/85	1.2796	18527	15346	26267	490.4	1809	2210	482.4	2.1	21631.2	16	7.94E-03
8/30/85	1.06	18606	15546	25579	522.2	1840	2351	476.8	2	27305	15	1.00E-02
10/1/85	0.95	17461	14867	24417	490.9	172.6	2254	456.3	2	23843	13	1.00E-02
10/31/85	0.84	17575	15181	25670	520.8	2015	2482	344.7	1.9	22878	14	1.26E-02
12/18/85	0.67	17652	16024	25427	565.2	2056	2556	439.5		23970	13	
AVERAGE	1.99	17110.61							1.99	25656.49		0.01
	Ave.Load=	409.05	lbs/day									

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.

9LA: 9 Level - Loadout Area @ 9 Level (Riley, 1990)

Note: 9LA was formerly Cherry Weir

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-Log pH
2/10/83	439.24								2.8	2500	14	1.58E-03
2/17/83									2.8	2500	11	1.58E-03
2/25/83	500.86								2.7	2700	12	2.00E-03
3/4/83	521.4								2.6	2800	13	2.51E-03
3/11/83	516.66								2.7	2080	12	2.00E-03
3/16/83	532.46								2.8	3000	14	1.58E-03
3/24/83	516.66	472.9	386.8	942.6				24.7	2.7	3500	15	2.00E-03
4/1/83	500.86								2.8	3400	14	1.58E-03
4/8/83	485.06	412.05	380.2	989.45	43.1				2.9	3400	14	1.26E-03
4/15/83	500.86	405.05	368.9	601.95	40.73				2.4	3300	15	3.98E-03
4/22/83	469.26	375.2	363.5	1102	40.7				2.7	3200	15	2.00E-03
4/29/83	455.04	380.9	360.6	883.5	38.82				2.7	3200	14	2.00E-03
5/6/83	469.26	342.2	340.3	636.8	36.65				2.8	3000	13	1.58E-03
5/13/83	500.86	364.2	338.4	710.9	39.92				2.6	2800	13	2.51E-03
5/24/83	469.26	336.6	329.1	607	37.71					2700	13	
6/3/83	469.26	400.6	346.9	699.55	50.455				2.3	3200	14	5.01E-03
6/9/83	469.26	389.8	324.5	749.2	43.62				2.8	2900	14	1.58E-03
6/15/83	469.26	355.7	299.15	686.65	43.41				2.8	2900	14	1.58E-03
6/24/83	469.26	298.6	289.55	581.1	37.865				2.7	2700	13	2.00E-03
6/29/83	469.26	318.2	268.77	627.13	40.016			9.164	2.9	2650	14	1.26E-03
7/6/83	455.04	298.2	267.12	600.88	37.328			8.333	2.9	2500	15	1.26E-03
8/3/83	439.24	234.61	206.02	408.97	34.681			6.753	3.1	2400	14	7.94E-04
9/9/83	439.24	219.17	194.55	440.64	31.854			6.011	2.8	1960	14	1.58E-03
10/6/83	366.56	226	190.5	449.8	29.84	56.985	55.175	6.472	2.8	1940	14	1.58E-03
11/10/83	395	205.2	187.1	388.9	32.07	55.11	52.67	4.906	3	1900	14	1.00E-03
12/8/83	316	199.9	162.5	393.4	30.73	52.17	47.77	4.624	2.7	1800	12	2.00E-03
1/26/84	300.2		207.6		32.77	60.46	55.28	4.738	2.8	2200	11	1.58E-03
2/9/84	316	234.55	232.85	473.8	38.035	74.89	63.425	5.252	3	2200	12	1.00E-03
2/23/84	316	232.8	233.2	517.7	36.52	69.89	60.7	5.234	2.8	2220	12	1.58E-03
3/8/84	316	252.8	228.9	489	34.87	69.95	59.94	5.346	2.6	2300	12	2.51E-03
3/22/84	442.4	242.2	217.2	460.6	32.32	63.42	55.7	5.384	2.3	1741.7	11	5.01E-03
4/5/84	395	347.2	341.8	616.8	40.88	78.92	81.6	7.057	2.6	2203.5	11	2.51E-03
4/19/84	426.6	349.8	350.1	653.7	35.74	74.05	79.91	7.815	2.4	2186.2	12	3.98E-03
4/26/84	442.4	451.1	488.9	855.5	41.08	88.22	88.42	12.99	2.7	2716.6	12	2.00E-03
5/10/84	410.8	476.4	466.6	813.5	42.84	85.69	94.63	11.11	2.5	2764.8	13	3.16E-03
5/23/84	458.2	596.8	663.9	1059	51.93	96.97	115	17.16	2.4	1623.3	13	3.98E-03
6/8/84	505.6		690.9	1140	57.31	102.2	112.1	19.96	2.4	3738.5	12	3.98E-03
6/12/84	489.8	618.2	641.2	1255	50.52	96.24	102.5	18.75	2.6	3640.6	8	2.51E-03
6/26/84	458.2	499.1	484.5	881.6	47.11	89.58	94.27	13.06	2.6	2790.1	13	2.51E-03
7/19/84	395	389.4	374	695	39.13	75.96	77.38	9.949	2.6	2397	13	2.51E-03
7/31/84	363.4	385.9	296.1	649.5	38.99	73.12	74.43	9.583	2.3	2212.1	12	5.01E-03
8/22/84	363.4	321.6	228.8	547.5	35.05	66.35	63.13	7.865				
9/19/84	331.8	267.5	240.3	467.3	32.08	60.22	58.32	6.494	2.8	1914.5	12	1.58E-03
1/25/85		230.9	209.7	419.9	32.04	59.91	55.92	5.2	2.6	1807.7	11	2.51E-03
2/21/85	372.401	217.1	189.1	405.7	31.92	56.54	53.16	4.4	2.6	1702.1	11	2.51E-03
3/12/85	345.454	227.9	210.6	440.6	28.7	54.05	51.28	5.5	2.5	1688.9	11	3.16E-03
3/28/85	386.22	242.5	243.5	448.4	29.23	57.63	61.59	4.8	2.9	1836.92	12	1.26E-03
4/11/85	553.23	193.8	178.8	400.3	30.54	66.48	52	4.3	3	1728.52	11	1.00E-03
5/1/85	553.23	506.6	523.9	879.7	42.1	81.98	82.79	11.94	2.8	2820.06	12	1.58E-03
5/21/85	620.68	660.3	678.9	1156	48.67	94.02	95.24	18.49	2.7	3596.23	12	2.00E-03
6/6/85	620.68	573.8	572	965.4	45.97	89.53		16.35	2.8	2828.18	13	1.58E-03
6/25/85	429.05	468.4	384.4	777.6	40.39	81.16	75.2	11.57	2.7	2548.41	12	2.00E-03
7/30/85	372.4	352.9	284.6	630.4	38.4	80.77	73.94	12.01	2.8	1700.05	18	1.58E-03
8/30/85	362	277.5	257.3	528.5	32.43	64.02	60.46	7.174	2.9	1836.92	12	1.26E-03
10/1/85	344	248.5	195.6	459.6	28.67	53.46	51.39	4.915	2.8	1552.33	12	1.58E-03
10/31/85	328	235.4	186	443.7	28.7	51.17	50.92	5.524	2.5	1371.22	12	3.16E-03
12/18/85	316	190.1	172.7	367.3	28.13	50.81	46.87	4.023	2.5	1750.17	13	3.16E-03
AVERAGE	435.80	344.29							2.66	2474.05		2.21E-03
	Ave. Load	1802.96	lbs/day									

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.

9BS: 9 Level - Barney Switch (Riley, 1990)

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-Log pH
3/24/83		4.219	14.64	86.11				0.835	4.9	560	18	1.26E-05
4/1/83									6.1	620	16	7.94E-07
4/8/83		3.891	4.336	87.03	20.33				5.8	570	14	1.58E-06
4/15/83		4.03	3.9765	80.955	22.14			0.465	5.3	580	18	5.01E-06
4/22/83		3.919	3.194	81.07	19.49				5.2	580	18	6.31E-06
4/29/83		3.708	2.8785	80.32	19.43				5.4	550	13	3.98E-06
5/6/83		3.469	2.842	67.92	18.17				5.5	490	13	3.16E-06
5/13/83		3.571	3.038	71.57	18.47				5.4	500	18	3.98E-06
5/24/83		3.595	2.749	68.69	19.26					460	15	
6/3/83		2.957	2.087	56.41	16.01				5	430	13	1.00E-05
6/9/83		3.508	2.592	66.27	19				5.7	470	13	2.00E-06
6/15/83		3.5195	2.7815	70.985	19.35				5.4	470	13	3.98E-06
6/24/83		3.47925	2.247	65.58	18.39				5.4	470	13	3.98E-06
6/29/83		3.61733	1.322	68.41	19.2233				5.8	460	14	1.58E-06
7/6/83		3.5135	1.572	64.895	18.255				5.8	480	14	1.58E-06
8/3/83		3.647	0.8495	69.655	18.5825				6.6	490	14	2.51E-07
9/9/83		3.774	2.203	73.3	18.97				5.2	500	13	6.31E-06
10/6/83		4.48	1.3525	74.215	19.375	43.66	16.095		5.4	510	12	3.98E-06
11/10/83		4.232	2.226	77.7	19.17	44.49	15.73	0.092	6	560	14	1.00E-06
12/8/83	145.752	4.489	1.214	80.22	27.11	42.71	17.08		5.5	500	10	3.16E-06
1/26/84	190.112	4.146	1.798	82.65	19.52	45.08	17.19		5.4	550	10	3.98E-06
2/9/84	155.258	4.0745	1.864	72.85	20.4	43.74	17.04		4.9	520	10	1.26E-05
2/23/84		3.96	1.963	78.15	22.56	44.91	16.19		4.8	530	10	1.58E-05
3/8/84	190.112	3.642	2.205	75.04	19.68	41.72	15.03		4.3	500	9	5.01E-05
3/22/84	253.482	4.029	1.115	71.11	16.04	38.66	14.97		6.3	204.39	12	5.01E-07
4/5/84	190.112	3.635	1.67	74.81	19.41	41.78	14.94		5.5	410.358	11	3.16E-06
4/19/84		3.412	0.879	72.6	17.34	41.25	14.97		6.4	436.747	11	3.98E-07
4/26/84	253.482	3.633	0.937	72.61	17.2	43.59	14.73		6.5	409.038	11	3.16E-07
5/10/84		3.432	1.158	73.44	17.27	40.24	13.98		4.6	427.986	10	2.51E-05
5/23/84		3.372	1.131	67.19	16.93	40.17	14.03		5.5	180.411	15	3.16E-06
6/8/84		3.096	1.17	62.65	16.81	38.22	13.4		6.2	418.52	13	6.31E-07
6/12/84		3.439	0.957	66.67	17.21	38.79	13.8		5.8	424.21	15	1.58E-06
6/26/84		3.208	2.364	72.3	17.77	39.32	13.6		4.5	365.558	17	3.16E-05
7/19/84		3.351	0.704	64.1	17.33	35.33	13.44		5.5	404.569	13	3.16E-06
7/31/84		3.459	0.41	60.92	17.39	34.19	13.07		4.5	295.92	14	3.16E-05
9/19/84		3.664	1.53	67.11	17.48	37	13.41		4.5	375.45	15	3.16E-05
1/25/85		3.9	2.1	77.8	19.51	42.41	14.98	0.2	5.8	405.84	13	1.58E-06
2/21/85		3.9	2.3	75.7	19.64	41.55	15.38		5.6	430.68	10	2.51E-06
3/12/85		3.7	2.2	72.9	18.38	40.9	15.07		6.5	419.79	13	3.16E-07
3/28/85		4.9	2.1	91.3	20.07	50.96	20.37		6.1	505.8	12	7.94E-07
4/11/85		5	0.9	65	14.52	35.74	15.16		5.9	376.74	14	1.26E-06
5/1/85		3.5	0.5	87.2	20.21	55.72	16		5.8	509.78	14	1.58E-06
6/6/85		3.4	2.1	70.3	20.57	44.25	13.63		6.3	483.94	15	5.01E-07
6/25/85		3.8	1.8	74	21.85	44.18	14.26		5.5	444.57	16	3.16E-06
8/30/85		4	1.6	79.5	19.63	43.72	14.6		6.9	466.71	13	1.26E-07
12/18/85		3.7	1.9	73	18.35	42.42	13.22	0.227	5.4	494.86	14	3.98E-06
AVERAGE	196.90	3.75							5.17	461.78		6.81E-06
	Ave. Load	8.88	lbs/day									

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.

9KT: 9 Level - Kellogg Tunnel (Riley, 1990)

Date	Flow	ZN	FE	S	CA	MG	MN	AL	PH	Conductivity	TEMP	-Log pH
1/25/83	1299.1								2.9	1890	20	1.26E-03
1/28/83	1362.47								2.9	2250	19	1.26E-03
2/10/83	1394.15								2.8	1920	19	1.58E-03
2/17/83	1394.15								2.7	1950	20	2.00E-03
2/25/83	1378.31								2.7	1920	21	2.00E-03
3/4/83	1568.42								3	2400	18	1.00E-03
3/11/83	1552.58								2.4	2030	17	3.98E-03
3/16/83	1394.15								2.8	2400	21	1.58E-03
3/24/83	1394.15	145.2	120	455.6				5.841	2.9	2600	26	1.26E-03
4/1/83	1441.68								2.4	2500	23	3.98E-03
4/8/83	1394.15	98.29	74.13	502.6	122.9				3	2500	21	1.00E-03
4/15/83	1283.25	93.85	65.35	412.6	139.9			3.203	2.8	2600	21	1.58E-03
4/22/83	1283.25	114.8	91.49	405.2	108.8			4.15	2.7	2600	23	2.00E-03
4/29/83	1330.78	116.3	96.3	393.4	97.88			4.457	2.6	1950	24	2.51E-03
5/6/83	1489.2	130.45	120	379.95	77.8			5.3545	2.9	2200	19	1.26E-03
5/13/83	1552.58	91.83	71.39	383	119.1			3.617	2.6	2300	22	2.51E-03
5/24/83	1346.62	92.51	64.76	413.5	127.6			1.495		2200	22	
6/3/83	1409.99	140.7	105.3	452	109.4			3.846	2.4	2500	22	3.98E-03
6/9/83	1346.62	186.5	145.3	491.2	53.43			5.499	2.8	2400	18	1.58E-03
6/15/83	1346.62	107.5	83.975	465.95	140.55			4.4285	2.9	2500	21	1.26E-03
6/24/83	1283.25	99.93	50.1	348.9	106.7			4.132	3.3	1990	21	5.01E-04
6/29/83	1394.15	137.4	115.635	426.15	107.5			5.3345	2.9	1720	20	1.26E-03
7/6/83	1489.21	92.477	52.877	394.73	136.833			2.4243	3	2300	22	1.00E-03
8/3/83	1283.25	137.55	109.175	377.13	54.397			7.1375	2.7	1900	19	2.00E-03
9/9/83	1219.88	86.975	50.53	326.35	89.41			3.9305	3	1840	20	1.00E-03
10/6/83	1204.04	151.45	196.8	474.5	132.1	132.65	62.62	1.57	3	2700	20	1.00E-03
11/10/83	1330.78	58.5	11.3	316.9	109.8	100.6	38.31	1.691	3.4	1720	21	3.98E-04
12/8/83	1299.1	53.79	10.76	292.7	93.17	84.7	35.77	2.165	2.5	1550	20	3.16E-03
1/26/84	1409.99	59.48	16.86		100.9	90.39	36.92	2.137	2.8	1650	17	1.58E-03
2/9/84	1394.15	62.715	37.605	334.65	113	127.3	45.62	2.0205	2.8	1770	19	1.58E-03
2/23/84	1726.85	68.98	19.06	328.3	107.9	106.1	39.51	1.82	2.8	1780	18	1.58E-03
3/8/84	1742.69	123.6	76.6	402.4	78.42	97.41	58.67	5.254	2.9	2200	16	1.26E-03
3/22/84	1948.64	57.92	13.59	309.2	101.1	102.4	36.33	1.205	2.4	1396.44	19	3.98E-03
4/5/84	1711.01	78.96	25.35	334.1	106.9	98.15	39.17	1.891	2.6	1340.89	15	2.51E-03
4/19/84	1901.12	121.2	77.9	351.4	52.19	78.05	53.09	5.282		1097.09	15	
4/26/84	1663.48	139	96.24	438.5	94.71	104.5	50.04	4.367	2.6	2039.13	14	2.51E-03
5/10/84	2012.02	139.5	88.16	404.9	82.52	91.76	45.99	3.961	2.8	1645.64	15	1.58E-03
5/23/84	2027.86	128.3	86.32	443.7	105.4	110.3	51.38	4.852	3	1826.41	18	1.00E-03
6/8/84	2313.03	251.9	188.6	596	96.53	112.7	78.84	9.569	2.9	2237.87	17	1.26E-03
6/12/84	2281.34	225.3	156.8	594.5	94.77	109.4	69.99	8.95	2.4			3.98E-03
6/26/84	2138.76	190.4	118.9	504	83.33	101	63.06	6.894				
7/19/84	2281.34	148.1	93.31	513.5	105.1	129.5	65.81	6.102	2.6	2096.67	15	2.51E-03
7/31/84	2043.7	86.07	22.98	332.9	104.4	95.46	42.04	3.344	2.3	1610.41	19	5.01E-03
9/19/84	1155.69	59.46	11.97		99.26	78.41	30.48	1.285	3.1	1546.59	17	7.94E-04
1/25/85	1854.69	72.6	24.7	285.4	86.13	78.18	35.78	2	2.6	1413.16	10	2.51E-03
2/21/85	2032.38	48.9	8.6	257.2	92.8	80.38	32.74	1.5	2.8	1362.66	19	1.58E-03
3/12/85	2070.04	52.8	12.2	270	92.22	88.8	34.66	1.7	3.1	1534.87	17	7.94E-04
4/11/85	2245.58	60.3	14.3	262.8	87.53	80.92	35.52	1.8				
5/1/85	2176.19	110	47.2	436.9	104.7	117.9	45.21	2.873	2.9	1869.43	19	1.26E-03
5/21/85	2314.99	151.8	101.9	433.6	77.03	90	52.46	5.899	2.7	2086.71	20	2.00E-03
6/6/85	2428	143.7	79.9	460.3	99.52	107	55.78	5.561				
6/25/85	2097.86	102.6	56.9	423.6	106.8	120.5	64.49	4.394	2.7	1980.85	21	2.00E-03
7/30/85	2092.91	121.3	51	464.1	110.2	148.9	73.74	4.868				
8/30/85	1965.01	97.5	41	366.2	93.44	99.04	51.32	3.974		1849.38	18	
10/31/85	1933.29	58.1	15.3		79.66	90.47	41.22	2.721				
AVERAGE	1662.34	110.79							2.72	1993.15		0.00
	Ave. Load=	2213.08	lbs/day									

Flow is in gpm, metals in mg/L, Conductivity in umhos/cm, and temperature in centigrade.